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THE DANISH GOVERNMENT INSTITUTE OF SEED PATHOLOGY
FOR DEVELOPING COUNTRIES . COPENHAGEN, DENMARK
No. 26

Identification of Seed-Borne Drechslera Species

by

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Reprinted from FRIESIA 10: 165-207. 1973.
Copenhagen

Contributions

from

The Danish Government Institute of Seed Pathology for Developing Countries

Copenhagen

No. 1. PAUL NEERGAARD: Seed-borne diseases. [Inspection for quarantine in Africa.] — Handbook for Phytosanitary Inspectors in Africa: 380—393. Lagos, Nigeria. 1969.

No. 2. PAUL NEERGAARD: Seed pathology of rice. — Plant Disease Problems. Proc. First International Symposium on Plant Pathology, New Delhi: 57—68. 1970.

No. 3. S. B. MATHUR & PAUL NEERGAARD: Seed health testing of rice II. Seed-borne fungi of rice in Philippines, India, Portugal and Egypt. Investigations on Trichoconis padwickii. — Plant Disease Problems. Proc. First International Symposium on Plant Pathology, New Delhi: 69—81. 1970.

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No. 6. M. A. BENOIT & S. B. MATHUR: Identification of species of Curvularia on rice seed. — Proc. Int. Seed Test. Ass. 35: 99—119 (2 plates). 1970.

No. 7. RAM NATH, PAUL NEERGAARD & S. B. MATHUR: Identification of Fusarium species on seeds as they occur in blotter test. — Proc. Int. Seed Test. Ass. 35: 121—144 (1 colour plate). 1970.

No. 8. RAM NATH, PAUL NEERGAARD & S. B. MATHUR: Drechslera longirostrata (Subram.) comb. nov. in seeds of rice and sorghum. — Proc. Int. Seed Test. Ass. 35: 145—150. 1970.

No. 9. J. S. GUPTA & PAUL NEERGAARD: Detection of chlamydospores of Protomyces macrosporus Ung. in Indian seed lots of coriander. — Proc. Int. Seed Test. Ass. 35: 151—155. 1970.

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No. 11. S. B. MATHUR & RAM NATH: Pestalotia guepini Desm. in seeds of Sorghum vulgare Pers. — Proc. Int. Seed Test. Ass. 35: 165—168. 1970.

No. 12. RAM NATH, S. B. MATHUR & PAUL NEERGAARD: Seed-borne fungi of mungbean (Phaseolus aureus Roxb.) from India and their significance. — Proc. Int. Seed Test. Ass. 35: 225—241. 1970.

No. 13. PAUL NEERGAARD: Seed-borne diseases and Indian agriculture. — Proc. Indian Science Academy 36: 222—237. 1970.

No. 14. DHARAM VIR, S. B. MATHUR & PAUL NEERGAARD: Control of seed-borne infection of Drechslera spp. on barley, rice, and oats with Dithane M-45. — Indian Phytopath. 23: 570—572. 1970.

No. 15. M. C. SRINIVASAN, P. CHIDAMBARAM, S. B. MATHUR & PAUL NEERGAARD: A simple method for inducing sporulation in seed-borne fungi. — Trans. Br. Mycol. Soc. 56: 31—35. 1971.

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No. 17. P. A. SANTAMARIA, A. BENOIT & S. B. MATHUR: Curvularia cymbopogonis, a hitherto unreported species pathogenic to rice in the Philippines. — Pl. Dis. Reptr. 55: 349—350. 1971.

No. 18. PAUL NEERGAARD: International and national cooperation in seed health testing and certification. — Proc. Int. Seed Test. Ass. 37: 117—138. 1972.

No. 19. S. B. MATHUR & PAUL NEERGAARD: Seed health testing of rice. IV. Effect of light and temperature on seed-borne fungi in the blotter test. — Proc. Int. Seed Test. Ass. 37: 723—730. 1972.

No. 20. F. C. GUERRERO, S. B. MATHUR & PAUL NEERGAARD: Seed health testing of rice. V. Seed-borne fungi associated with abnormal seedlings of rice. — Proc. Int. Seed Test Ass. 37: 985—997. 1972.

Særtryk af FRIESIA X, 3: 165-207. — August 1973.

IDENTIFICATON OF SEED-BORNE DRECHSLERA SPECIES

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SUMMARY

Habit and diagnostic characters of 25 species of *Drechslera* growing on naturally infected seeds of tropical and temperate crops incubated on blotters have been described. Host range and economic importance of each species are discussed and descriptions supported by photographs and line drawings. The species studied are *Drechslera avenae, D. bicolor, D. catenaria, D. cynodontis, D. dematioidea, D. dictyoides* f. sp. *dictyoides, D. dictyoides* f. sp. *perennis, D. graminea, D. halodes, D. hawaiiensis, D. longirostrata, D. maydis, D. micropa, D. monoceras, D. oryzae, D. rostrata, D. sacchari, D. siccans, D. sorghicola, D. sorokiniana, D. teres, D. tetramera, D. tuberosa, D. turcica, D. urochloae,* and *D. victoriae.*

Closely resembling species have been arranged into 8 groups and the differentiating characters of species within each groups are discussed.

INTRODUCTION

Diagnostic growth characters for the identification of common species of *Curvularia* and *Fusarium* developing on infected seeds in the blotter test during routine seed health testing were described in two previous publications from this Institute (BENOIT & MATHUR 1970, RAM NATH, NEERGAARD & MATHUR 1970a). During the past few years investigations have been carried out on the morphological characters of seed-borne species of *Drechslera* in the blotter test and their colony characters on agar media. It was established that most

of the *Drechslera* species form dark colonies on agar, very similar to those of *Alternaria* and *Curvularia*. Macroscopic identification based on colony characters in the agar test is difficult for most of the species whereas they are easily distinguishable in the blotter test. As a consequence, results reported in this paper are mainly concerned with the growth characters of 25 species of *Drechslera*, as they appear on seeds in the blotter test under stereoscopic binocular microscope (6-50 ×), and to their conidial morphology under the compound microscope. In addition, colony characters of the only four distinguishable species on agar are described. The descriptions are supplemented with photographs and comments on economic significance and host range.

MATERIALS AND METHODS

Seed samples of many crops (see the names of the crops under each species), infected by various species of *Drechslera*, received from a number of countries, were tested by two incubation methods.

Blotter test: The seeds were sown on three layers of moistened blotters placed in plastic petri dishes at the rate of 25 seeds per dish except in the case of maize where the number was 10 per dish. The plates were incubated at 20° C (± 1) in environment controlled rooms under cycles of 12 hours near ultraviolet light (NUV) and 12 hours darkness. After 7 days of incubation, seeds were examined for growth characters of *Drechslera* spp. under stereo-binocular microscope at 6-50 × magnification. In addition to the normal blotter test, the freezing method recommended by LIMONARD (1968) was used for barley and oats. Thus 25 seeds per plate were sown on blotters, kept in total darkness at + 20° C (± 1) for 24 hours followed by 24 hours of freezing at — 20° C. The plates were then placed under cycles of 12 hours of NUV and darkness at + 20° C (± 1) for 5 days. On the eighth day the growth characters as well as the percentage of infection were recorded, based on 400 seeds per test.

Agar plate test: Ten seeds per plate were sown on potato dextrose agar (PDA) after pretreatment for 10 minutes in 1 per cent chlorine as sodium hyphochlorite solution. The incubation conditions were the same as described under the blotter test. On the eighth day the colonies of *Drechslera* species were examined for mycelial growth, colour and nature of the colony, sporulation, pigmentation as well as zonations.

Growth of different species on seeds in the blotter test and in some cases colonies on agar were photographed. Whenever necessary, slides were prepared and identification confirmed after having examined the morphology of conidia and conidiophores. Diagramatic sketches of sporulating structures were also made.

For the measurement of conidial size, mounts were made in water from the colonies on blotter and 20 to 25 spores taken at random measured. Detailed notes were made on colour, shape, nature of hilum and other special destinguishing characters for each of the species from each host.

Simple terms such as "short", "medium" and "long" have been used in describing the relative sizes of conidiophores on seeds in the blotter test. Their measurements have, therefore, been deleted from the descriptions. "Short" is below 200 μ, "medium' is 200-400 μ and "long' above 400 μ.

Single spore isolations were made of all species. Identifications were confirmed at the Commonwealth Mycological Institute (CMI), Kew, Surrey, England.

The terminology for colours of colonies, conidiophores and conidia is based on the Mycological Colour Chart, published by RAYNER (1970).

1. **Drechslera avenae** (EIDAM) SCHARIF

Helminthosporium avenae EIDAM
Perfect state: *Pyrenophora avenae* ITO & KURIB.
(Plate 1)

On seed: Mycelium grey, with or without greyish white to white tufts. Conidiophores dark brown to black, medium to long, single or in groups of 2 to 3. Conidia acropleurogenous at wide intervals, light to olivaceous brown, cylindrical with rounded ends, sometimes little broader at the base, generally single, rarely in chains of 2 to 3. Producing pycnidia on some seeds.

On agar: Colonies grey to black, mycelium coarse and radiating with characteristic milky white to greyish tufts. Reverse black in the center gradually becoming olive-greyish to brownish-black towards the periphery. Some colonies are white due to the whitish tufts. In some samples pink to brick-red pigmentation is found in agar.

Conidia (under compound microscope): Olivegreen to olivaceous brown, straight, cylindrical, scar wide, dark, conspicuous, 32.3-110.5 × 11.9-17.0 μ, 2-6-septate.

Economic importance: The fungus causes pre-emergence and post-emergence seedling blight and leaf stripes of young plants and leaf spot or blotch of mature oat plants (SPRAGUE 1950, DICKSON 1956, DE TEMPE 1964, MALONE & MUSKETT 1964), cosmopolitan (CMI map No. 105, 1966), important in cool and moist climates (DE TEMPE l. c.). REKOLA, RUOKOLA & KURTTO (1970) reported 2-10 per cent losses in oats in Finland.

Occurrence: The fungus was recorded in seeds of *Avena sativa* and *Coriandrum sativum*.

2. **Drechslera bicolor** (MITRA) SUBRAM. & JAIN

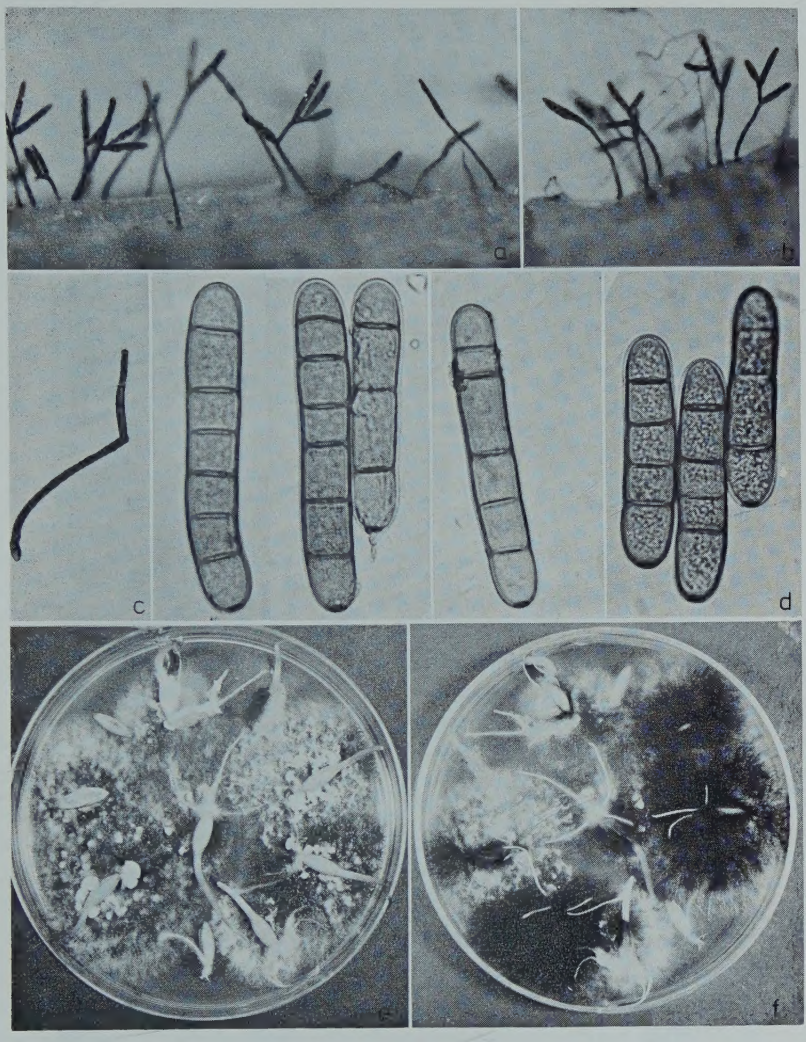
Helminthosporium bicolor MITRA
Bipolaris bicolor (MITRA) SHOEM.
Perfect state: *Cochliobolus bicolor* PAUL & PARBERY
(Plate 2)

On seed: Mycelium scanty, greyish to light brown. Conidiophores brown, medium, arising in clusters of 2 to 3. Conidia acropleurogenous produced at short intervals towards the upper half, blackish brown, shiny, straight or slightly curved, cylindrical or long ellipsoid. Tips of conidia reflect light in many cases.

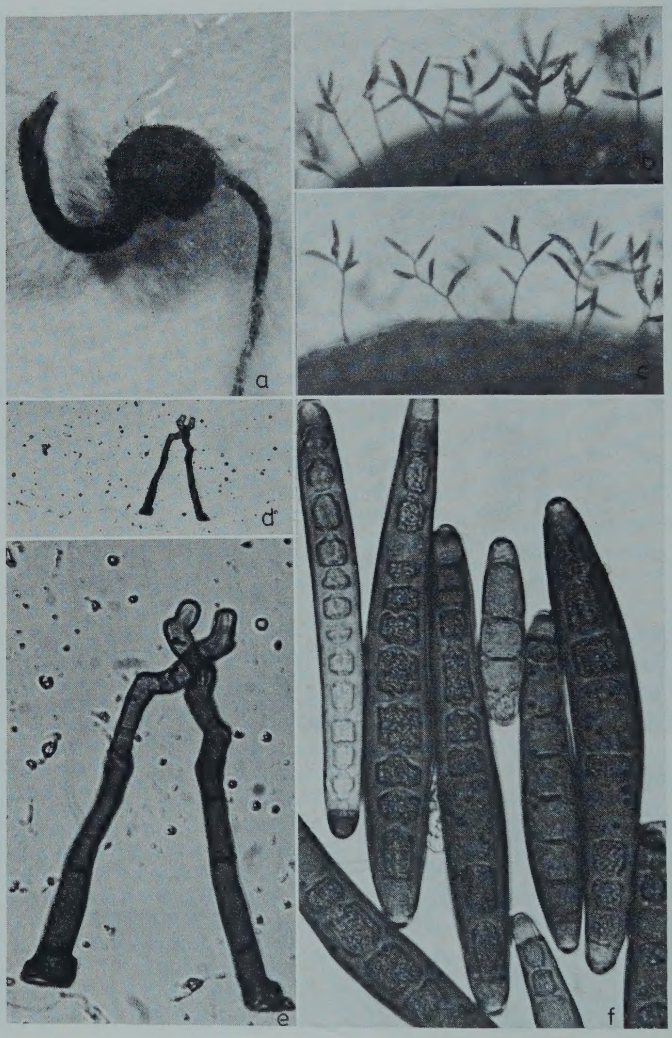
Conidia (under compound microscope): Dark grey or smoky (fuligenous) brown or olivaceous brown, cylindrical or subcylindrical or long ellipsoid, broader in the middle or just below the middle, tapering to rounded ends, tapering more pronounced in the isolate of *Eleusine coracana*. Terminal septa darker and thicker in most cases, hilum within the contour of the basal cell, 54.4-124.1 × 13.6-18.7 μ, 7-14-septate.

Economic importance: Reported to cause foot and root rot of wheat and barley seedlings in India (MITRA 1931). CHATTOPADHYAY & CHAKRABARTI (1968) and GHURDE (1967) regard it as a weak parasite of wheat. PUTTERILL (1954) isolated the fungus from wheat showing foot rot, and from lesions with dull red borders on the leaves of *Sorghum halepense* and *S. verticilliflorum*. So far *Drechslera bicolor* has not been reported as seed-borne. The two samples of finger millet from India and Nepal were heavily infected. It caused browning in roots, rotting of the coleoptile in the blotter test, and brown spots on the leaves of seedlings in the inoculation experiment.

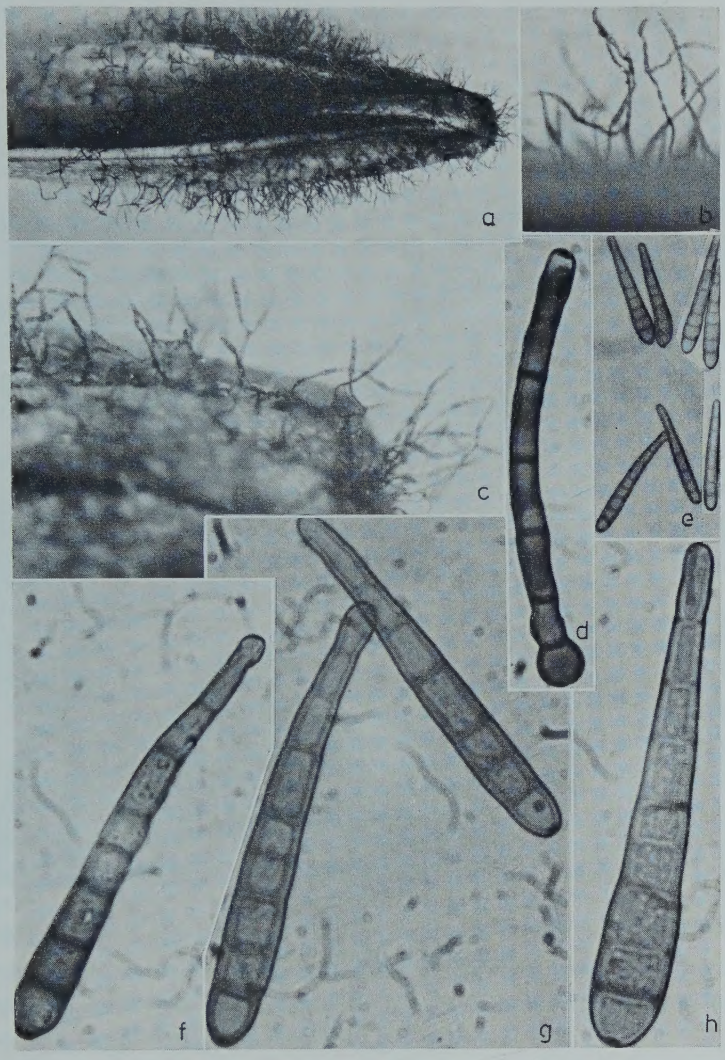
Occurrence: The species was encountered in seed of *Brassica oleracea* var. *acephala*, *Bromus unioloides*, *Coriandrum sativum*, *Eleu-*



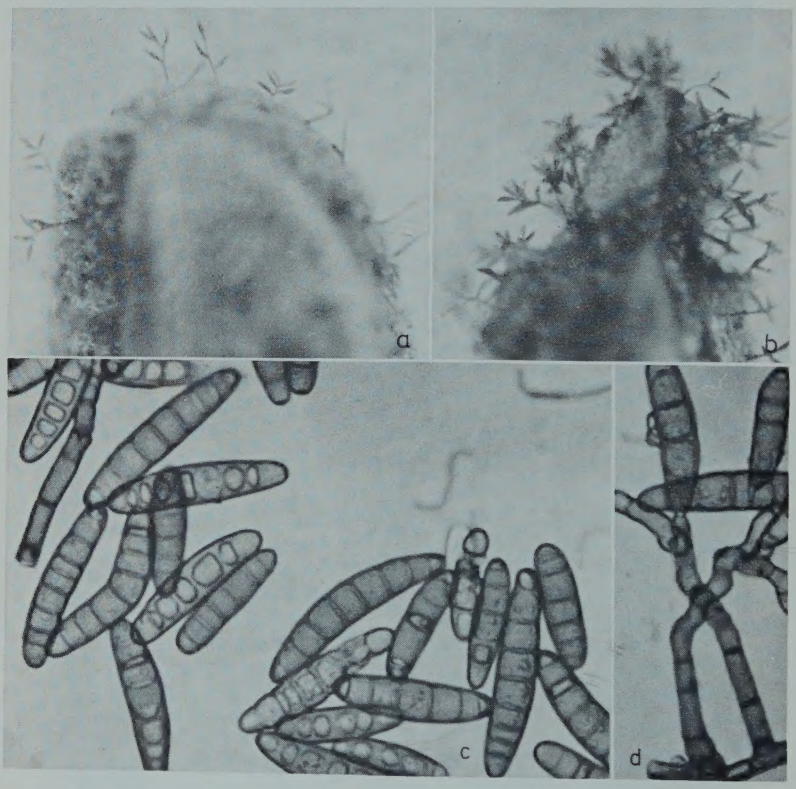
Drechslera avenae. (a-b) on oat seed—100×; (c) conidiophore—250×; (d) conidia—1000×; (e-f) colonies on PDA, (e) top view and (f) reverse view.



Drechslera bicolor. (a) on finger millet seed, browning of root and rotting of coleoptile—15×; (b-f) conidiophores and conidia; (b-c)—100×, (d) 250×, (e-f) 1000×.



Drechslera catenaria. (a-c) on *Festuca pratensis* seed, (a) 30×, (b-c) 100×; (d-h) conidia and conidiophore, (e) 250×, (d-f-h) 1000×.



Drechslera cynodontis. (a-b) on *Ammi majus* seed—100×; (c-d) conidia and conidiophores—1000×.

sine coracana, Foeniculum vulgare, Lycopersicon esculentum, Oryza sativa, Pennisetum glaucum, Sorghum bicolor, S. vulgare, Spinacia oleracea, and *Triticum aestivum.*

3. **Drechslera catenaria** (Drechs.) Ito

Helminthosporium catenarium Drechs.
(Plate 3)

On seed: Conidiophores short or medium, arising singly or in groups. Conidia at the tips, single or acropleurogenous, or in chains of 2 to 3; secondary conidiophores present. Conidia fuliginous brown, obclavate, tapering towards the apex.

Conidia (under compound microscope): Fuliginous brown, straight obclavate or subcylindrical, basal cell longer than wide, hemi ellipsoidal, tapering towards the apex, widest at the second cell or second septum, basal scar within the contour of the cell, 64.7-127.6 × 12.9-17.0 μ, 3-6-septate.

Economic importance: Leaf spots in *Cinna arundinacea, Festuca arundinacea* subsp. *pratensis, Lolium multiflorum,* and *L. perenne* (Drechsler 1923, Andersen 1959).

4. **Drechslera cynodontis** (Marig.) Subram. & Jain

Helminthosporium cynodontis Marig.
Bipolaris cynodontis (Marig.) Shoem.
Perfect state: *Cochliobolus cynodontis* Nelson
(Plate 4)

On seed: Conidiophores fuliginous to dark brown, arising singly or in groups of 2 or 3, short, straight or slightly bent. The first conidium borne at a short distance from the base of the conidiophore, 4 to 9 conidia borne acropleurogenously at the geniculated tip; conidia fuliginous to light brown, ellipsoid to ovate, broader in the middle with rounded ends, straight or slightly curved.

Conidia: (under compound microscope): Light to olivaceous brown, ellipsoid with rounded ends, straight or slightly curved, uniform in colour, dark scar within the contour of the basal cell, 32.3-68.0 × 8.5-13.6 μ, 5-9-septate.

Economic importance: Occurs on many grasses, especially Bermuda grass *(Cynodon dactylon)* causing dark brown lesions,

withering and bleaching of leaves (PUTTERILL 1954, DICKSON 1956).

Occurrence: The species was encountered in seeds of *Agropyron elongatum, Ammi majus, Hordeum vulgare, Lycopersicon esculentum,* and *Triticum aestivum.*

5. **Drechslera dematioidea** (BUB. & WROB.) SUBRAM. & JAIN

Helminthosporium dematioideum BUB. & WROB.
(Plate 5)

On seed: Conidiophores light brown, short, slender, arising singly or in twos. Conidia acropleurogenous, dark brown, clavate.

Conidia (under compound microscope): Yellowish brown, clavate, broader at the tip, tapering towards the base ending in a wide dark scar, basal cell lighter in colour, 24.6-40.8 × 9.3-15.3 μ, 3-5-septate.

Economic importance: DRECHSLER (1923) observed the species on the inflorescence as well as withered foliage of *Agrostis alba* and *A. perennans.* In South Africa it was found associated with withered or dead leaves of *Cynodon transvaalensis, C. bradleyi* and *C. dactylon* (PUTTERILL 1954). ANDERSEN (1954) observed the species on *Dactylis glomerata* as well as on the seeds of *Festuca duriuscula.*

Occurrence: The species was recorded on seeds of *Chrysanthemum cinerariifolium* and *Hordeum vulgare.*

6 a. **Drechslera dictyoides** (DRECHS.) SHOEM. f. sp. **dictyoides**

Helminthosporium dictyoides DRECHS.
Perfect state: *Pyrenophora dictyoides* PAUL
(Plate 6)

On seed: Conidiophores short, narrow, light to medium brown, with bulbous base bearing conidia either singly or acropleurogenously. Conidia fuliginous to light brown, tapering uniformly to rounded tips, sometimes secondary conidia formed from a protrusion of the primary conidium. Conidia sometimes long and slightly curved towards the tip. In most cases inflated basal cell clearly visible even under stereobinocular microscope. Pycnidia black with long setae.

Conidia (under compound microscope): Fuliginous brown, obclavate, basal cell wider and inflated, hemispherical, constricted at

Drechslera dematioidea. (a) on *Chrysanthemum cinerariifolium* seed—100×; (b) conidia—1000×.

Drechslera dictyoides f. sp. *dictyoides*. (a) on *Festuca pratensis* seed—100×; (b-c) conidia and conidiophore—1000×.

Drechslera dictyoides f. sp. *perennis*. (a-c) on *Lolium perenne* seed—100×; (d-e) conidia and conidiophore—1000×.

Drechslera graminea. (a-b) on barley seed—100×; (c-d) conidia—1000×.

the first septum, uniformly tapering towards rounded apex; scar clear, 6.2-142.8 × 11.9-18.7 μ, 3-8-septate.

Occurrence: This *forma specialis* was recorded only on seeds of *Festuca arundinacea* subsp. *pratensis*.

6 b. **Drechslera dictyoides** f. sp. **perennis** (Braverman & Graham) Shoem.

Helminthosporium dictyoides f. sp. *perennis* Braverman & Graham
Perfect state: *Pyrenophora dictyoides* Paul
(Plate 7)

On seed: Similar to *Drechslera dictyoides* f. sp. *dictyoides*. The conidiophores in some cases medium to long, straight, dark brown and the first conidium borne at shorter distance from the base; the inflated basal cell commonly absent.

Conidia (under compound microscope): Fuliginous brown, obclavate, tapering towards the apex, wider at the basal cell (septa), straight, with a rounded tip. Slightly constricted at the basal septum; secondary conidium borne from a protrusion of the primary conidium, 66.3-130.9 × 11.9-15.3 μ, 3-7-septate.

Economic importance: Causes net blotch of *Festuca elatior* and *F. arundinacea* in United States, on *Lolium* spp. in England, and on *Lolium multiflorum* and *Festuca elatior* in Wales (Braverman & Graham 1960). They created two *formae speciales, D. dictyoides* f. sp. *dictyoides* causing net blotch of *Festuca elatior* and *F. arundinacea* and *D. dictyoides* f. sp *perennis* infecting *Lolium perenne, L. multiflorum,* and *L. perenne* × *F. elatior* hybrid.

Occurrence: It was recorded on seeds of *Lolium perenne*.

7. **Drechslera graminea** (Rab. ex Schlecht.) Shoem.

Helminthosporium gramineum Rab. ex Schlecht.
Perfect state: *Pyrenophora graminea* Ito & Kurib.
(Plate 8)

On seed: Conidiophores dark brown and shiny, short to medium, straight. Conidia acropleurogenous, oblong to ellipsoid, much darker than conidiophores, mostly in short chains of 2 to 3, sometimes in long chains of 5 to 6 particularly under excessive moist conditions

or on frozen seeds. (Such growth may be confused with that of *Alternaria* but in the latter conidia taper towards tips).

Conidia (under compound microscope): Cylindrical, olivaceous brown, basal cell short and broad, small secondary conidiophores present, scar clean, broad and short, 27.2-64.6 × 11.9-18.7 μ, 1-4-septate.

Economic importance: Causes leaf stripe disease of barley, becomes systemic in plants infected from seed, widespread (Noble & Richardson 1968). Severely infected seed is thin, mottled, dark brown or pink brown (Noble 1966). In German Democratic Republic, 10 to 20 per cent of the crops have been severely infected (Masurat & Stephan 1962). In the Tashkent and Samarkand regions of Uzbekistan, it causes losses in barley of up to 10 per cent (Rasulev & Kravtsova 1970).

Occurrence: The species was recorded only in seeds of *Hordeum vulgare.*

8. **Drechslera halodes** (Drechs.) Subram. & Jain

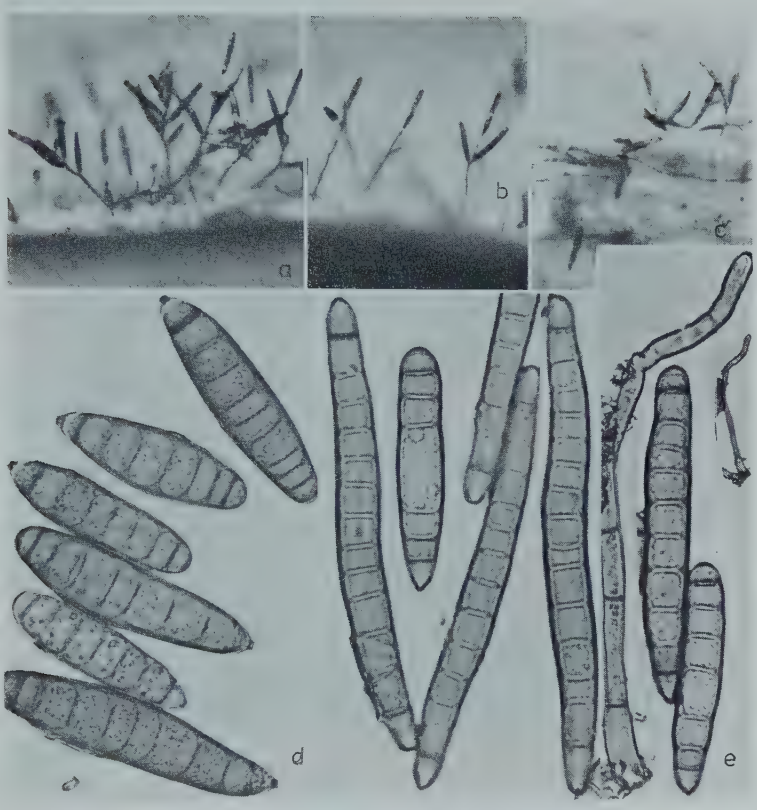
Helminthosporium halodes Drechs.
Bipolaris halodes (Drechs.) Shoem.
(Plate 9)

On seed: Conidiophores dark brown, short to medium, single or in groups of 2 to 4. Conidia acropleurogenous, fuliginous brown to shiny black, long ellipsoid or cylindric, dark end septa often visible.

Conidia: (under compound microscope): Fuliginous to olivaceous brown or dark brown, ellipsoid to long ellipsoid or cylindric, never rostrate, broader in the middle, tapering towards rounded ends, lighter in the terminal cells or towards the end of terminal cells, end septa darker and thicker, hilum dark or of the same colour as the end cell and protuberant, 13.6-191.4 × 10.2-22.1 μ, 3-18-septate.

Economic importance: Causes seedling disease of sugar cane (Subramanian 1936, Singh & Singh 1968) and foot rot of wheat (Mitra 1931, Putterill 1954). Black blotching of seedling of maize in germination test and seed mould in rice were due to this species (Noble & Richardson 1968).

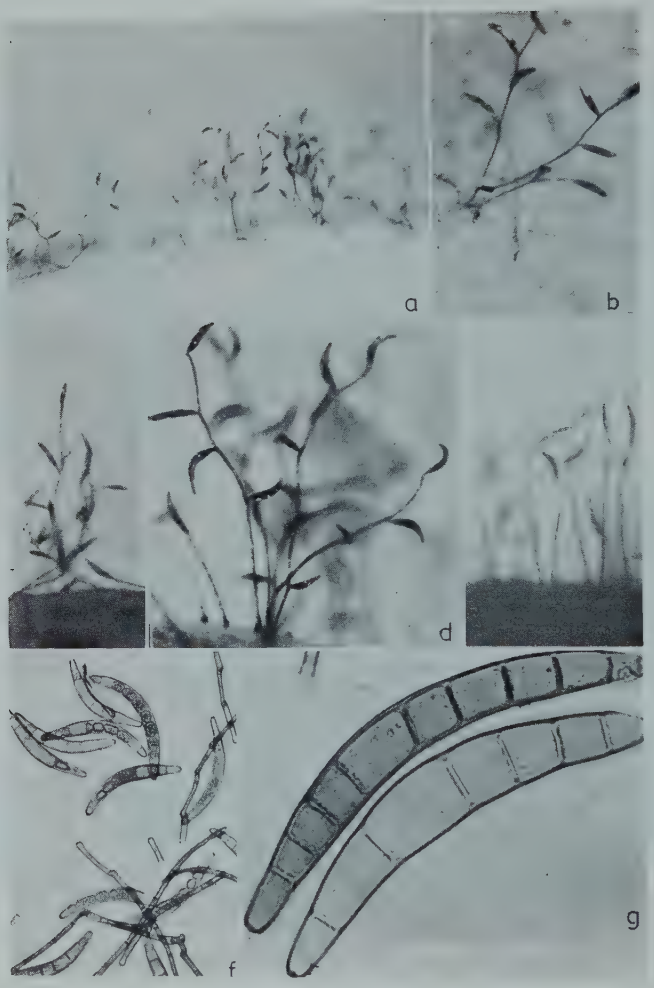
Occurrence: *Drechslera halodes* was recorded on seeds of *Hordeum vulgare, Lablab niger, Oryza sativa, Sesamum indicum, Setaria italica, Sorghum vulgare, Triticum aestivum,* and *Vigna sinensis.*



Drechslera halodes. (a-b) on barley seed—100×; (c) on rice seed—100×, (d-e) conidia and conidiophore—1000×.

Drechslera hawaiiensis. (a) on barley seed—50×; (b-d) conidia and conidiophore, (b & d) 1000×, (c) 250×.

Drechslera longirostrata. (a) on rice seed—50×; (b-d) on barley seed, (b-c) 50×, (d) 100×; (e-g) conidia and conidiophore, (e & g) 250×, (f) 1000×.



Drechslera maydis. (a-b) on maize seed, (a) 50×, (b) 100×; (c) on pearl millet—100×; (d) on rice—100×; (e) on sorghum—100×, (f) conidia and conidiophore—250×; (g) conidia—1000×.

9. **Drechslera hawaiiensis** (Bugnicourt) Subram. & Jain

Helminthosporium hawaiiense Bugnicourt
(Plate 10)

On seed: The growth is similar to *Drechslera tetramera* (see page 195), with shorter conidiophores. Conidia light to dark, slender, borne in clusters towards the apex pointing out in different directions (not perpendicular to the conidiophores).

Conidia (under compound microscope): Fuliginous to olivaceous brown, cylindric or cylindroclavate, hilum within the contour of the basal cell, 11.9-39.1 × 6.2-11.9 μ 1-7-septate (4-6 septa common).

Economic importance: In 1955, Bugnicourt described this species from rice seeds, but no literature is available regarding the damage caused by the fungus in the field. Recently Rizvi & Kafi (1969) reported it along with *D. halodes* in connection with leaf spots of lawns and turfs.

Occurrence: The species was encountered on seeds of *Abelmoschus esculentus, Althaea rosea, Avena sativa, Brassica oleracea* var. *capitata, Bromus unioloides, Calendula officinalis, Capsicum annuum, Cenchrus ciliaris, Coriandrum sativum, Cucumis melo, C. sativus, Cucurbita pepo, Delphinium ajacis, Dolichos lablab, Helianthus annuus, Hibiscus sabdariffa, Hordeum vulgare, Iberis amara, Lactuca sativa, Linum marginale, Oryza sativa, Panicum miliaceum Pennisetum glaucum, Phaseolus aureus, P. mungo, Phlox drummondii, Sesamum indicum, Solanum melongena, Sorghum vulgare, Tagetes* sp. *Triticum aestivum,* and *Vigna sinensis.*

10. **Drechslera longirostrata** (Subram.) Subram.*)

Helminthosporium longirostratum Subram.
(Plate 11)

On seed: The species is characterized by very long, slender, acropleurogenous, rostrate conidia on short to medium conidiophores. Apical cell in some conidia bulbous. Dark, thick basal septum clearly

*) The change from *Helminthosporium longirostratum* Subram. to *Drechslera longirostrata* (Subram.) Subram. was already made by Subramanian at the 1st International Symposium on Plant Pathology, held at Delhi in 1967 (Subramanian 1970). But this change came to our notice only recently and, therefore, the authority cited in the paper on *D. longirostrata* (Subram.) Ram Nath, Neergaard & Mathur (1970 b) should be read as cited above.

visible in many conidia. In some cases on the same conidiophore along with rostrate conidium, a short ellipsoid conidium is also produced.

Conidia (under compound microscope): Olivaceous brown, very long, broadest around the basal septum, narrowing gradually towards the apex, ends rounded; basal septum and sometimes apical septum darker and thicker; apical cell sometimes swollen, hilum protuberant, 62.9-462.0 × 11.9-25.5 μ, 6-26-septate.

Economic importance: In 1956, SUBRAMANIAN described this species as *Helminthosporium longirostratum* from dead leaves of *Borassus flabellifer*. RAM NATH, NEERGAARD & MATHUR (1970 b) reported the species on seeds of pearl millet, rice, sorghum, and wheat causing leaf spots.

Occurrence: The species was recorded on seeds of *Althaea rosea, Cuminum cyminum, Eleusine coracana, Foeniculum vulgare, Oryza sativa, Pennisetum glaucum, Phaseolus aureus, Sesamum indicum, Sorghum bicolor, S. vulgare, Triticum aestivum,* and *Vigna sinensis.*

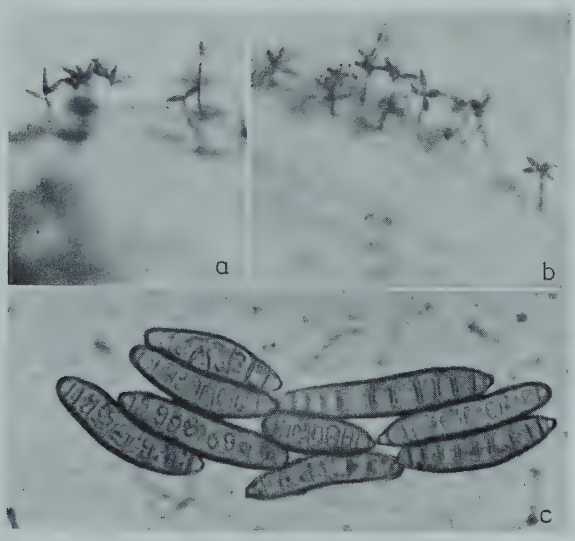
11. **Drechslera maydis** (NISIKADO) SUBRAM. & JAIN

Helminthosporium maydis NISIKADO
Bipolaris maydis (NISIKADO) SHOEM.
Perfect state: *Cochliobolus heterostrophus* (DRECHS.) DRECHS.
(Plate 12)

On seed: Conidiophores brown, medium to long, commonly long, slender, flexuous, single or in groups of 2 or 3, bearing conidia acropleurogenously at wider intervals. Under moist or humid conditions the conidiophores become filamentous, difficult to differentiate from hyphae. Conidia fuliginous to light brown, slender, typically curved, lighter in colour than *Drechslera oryzae.*

Conidia (under compound microscope): Fuliginous to light olivaceous brown, typically curved, the curvature more pronounced than in any other related species, e. g. *D. oryzae,* sharply tapering towards rounded ends, base clear and flat, hilum within the contour of the basal cell and mostly inconspicuous, 61.2-164.9 × 10.2-20.4 μ, 4-12-septate.

Economic importance: The species occurs in both temperate and tropical areas, but predominant in the latter (TARR 1962) and widespread (CMI map No. 346, 1964). Under natural conditions



Drechslera micropa. (a-b) on *Paspalum notatum* seed—100×, (c) conidia—1000×.

Drechslera monoceras. (a) on rice seed—100×; (b) on wheat seed—100×; (c) conidia—1000×; (d) conidiophores—250×.

the pathogen has been reported from maize, teosinte and sorghum. It is especially destructive on maize with physiologic races known and seed transmission well established (Drechsler 1925, Ullstrup 1941, 1970, Smith et al. 1970, Farrar 1970, Moore 1970, Crosier & Braverman 1971, Tuite & Caldwell 1971, White & Ellet 1971, Boothroyd 1971).

Occurrence: The species was observed on seeds of *Capsicum annuum, Coriandrum sativum, Oryza sativa, Panicum miliaceum, Pennisetum glaucum, Setaria italica, Sorghum vulgare,* and *Zea mays.*

12. **Drechslera micropa** (Drechs.) Subram. & Jain

Helminthosporium micropus Drechs.
Bipolaris micropa (Drechs.) Shoem.
(Plate 13)

On seed: Conidiophores fuliginous to light brown, single, short, slender, straight. Conidia acropleurogenous in cluster at tips, fuliginous to light brown, small, ellipsoid, broader in the middle, tapering towards ends.

Conidia (under compound microscope): Fuliginous to olivaceous brown, ellipsoid, broader in the middle, straight or slightly curved, gradually tapering towards both ends, apex rounded, small protruding hilum, 37.4-52.7 × 11.9-13.6 μ, 4-7-septate.

Economic importance: The species was described from leaves of young plants of *Paspalum boscianum* (Drechsler 1923) and not reported seed-borne so far.

Occurrence: It was recorded in seeds of *Paspalum notatum.*

13. **Drechslera monoceras** (Drechs.) Subram & Jain

Helminthosporium monoceras Drechs.
Bipolaris monoceras (Drechs.) Shoem.
(Plate 14)

On seed: Conidiophores light to dark brown becoming lighter towards the apex, long, flexuous, single or in groups of 2 or 3. Conidia either single or acropleurogenous at wider intervals like *Drechslera maydis* and *D. turcica* in a loose manner, fuliginous to light brown, fusoid, straight or curved, tapering towards acute ends, basal cell much narrower.

Conidia (under compound microscope): Olivaceous brown, fusoid, thin walled, mostly straight or slightly curved, broader in the middle, tapering acutely towards both ends, basal cell long and narrow, hilum slightly darker and protuberant, 85.0-161.5 × 15.3-20.4 μ, 5-10-septate.

Economic importance: DRECHSLER (1923) described this species from dark-brown or chocolate coloured spots on leaves of *Echinochloa crus-galli*. NISIKADO (1928) also reported leaf blight of the same host.

Occurrence: The species was recorded on seeds of *Oryza sativa* and *Triticum aestivum*.

14. **Drechslera oryzae** (BREDA DE HAAN) SUBRAM. & JAIN

Helminthosporium oryzae BREDA DE HAAN
Bipolaris oryzae (BREDA DE HAAN) SHOEM.
Perfect state: *Cochliobolus miyabeanus* (ITO & KURIB.) DRECHS. ex DASTUR
(Plate 15)

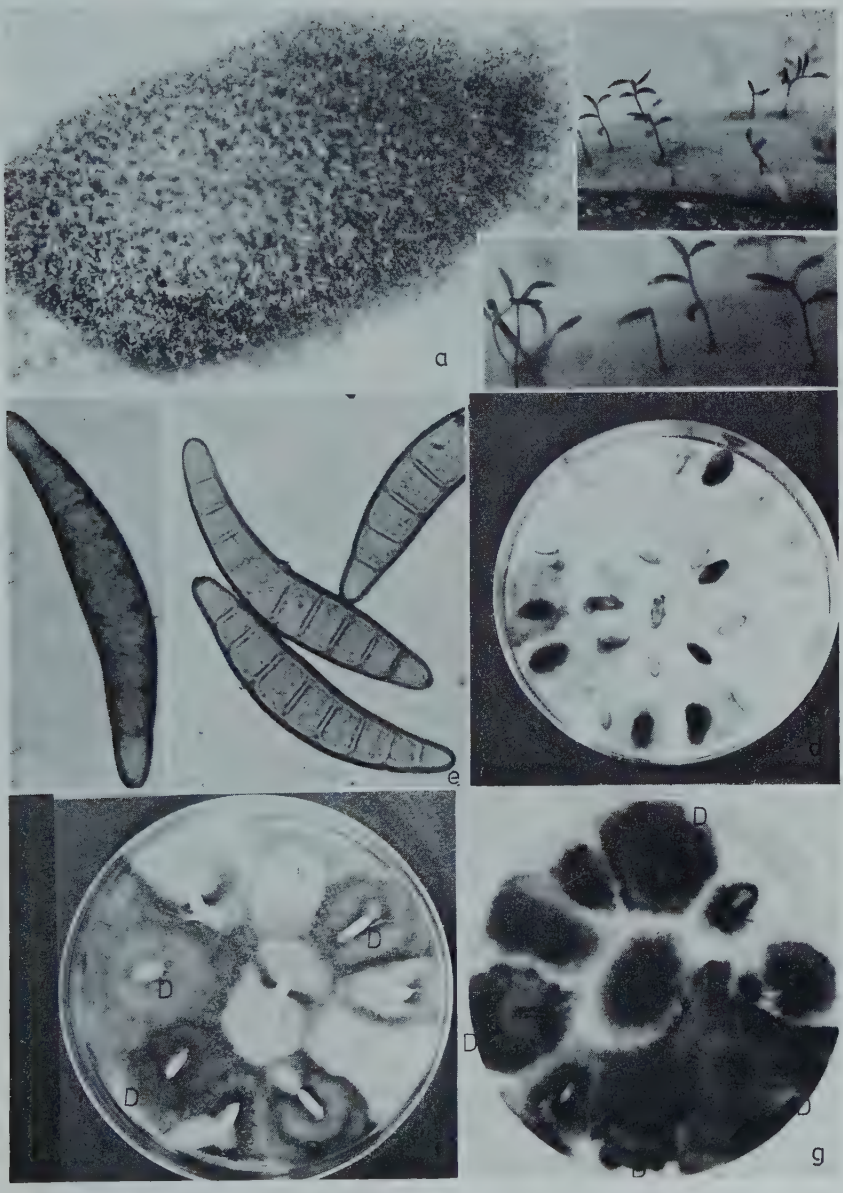
On seed: Two types of colonies. a) Greyish black fluffy mycelial growth with slender conidiophores and conidia covering a part or whole of the seed, often extending on to the blotter. b) Mycelium scanty, conidiophores straight or flexuous, brown, bearing dark brown conidia acropleurogenously. Conidia curved and tapering towards the ends, olivaceous to dark brown.

On agar: Top view: Colonies spreading, mouse grey (ashy grey) to dark greenish grey, mycelium fluffy, aerial, cottony. In most cases sporulation sparse, in few moderate. Some colonies smooth with shiny edges and not fluffy.

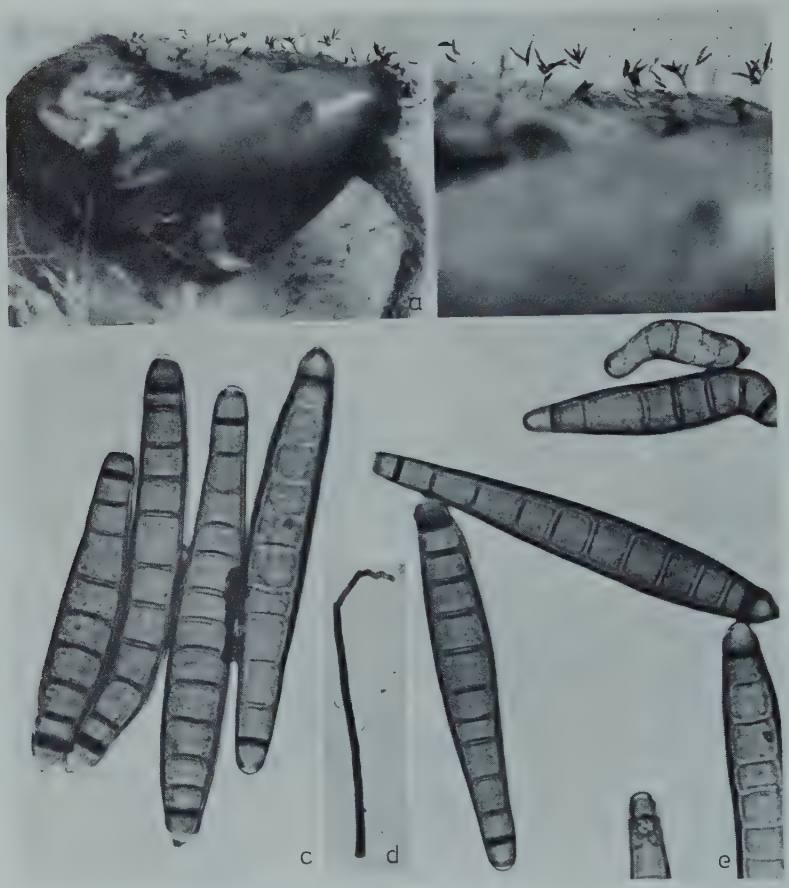
Reverse view: Colonies light grey olivaceous with brownish tinge, not dense, mycelium fine, margin wavy, in some cases little darker towards the margin or at the junction of two colonies, black around the seed.

Conidia: (under compound microscope): Fuliginous to olivaceous brown, curved, widest in the middle or just above middle, tapering to rounded ends; base more rounded, not flat or definite; hilum in most cases inconspicuous, within the contour of the basal cell seen as a papilla-like structure, but in few cases a clear scar visible, 93.5-156.4 × 13.3-20.4 μ, 7-11-septate.

Economic importance: It is a major pathogen of rice, widespread (CMI map No. 92, 1962) and causes heavy losses (SUN-



Drechslera oryzae. (a-c) on rice seed, (a) 15 ×, (b) 50× , (c) 100× ; (d) on blotter; (e) conidia—1000× ; (f-g) colonies on PDA, (f) top view and (g) reverse view.



Drechslera rostrata. (a-b) on pearl millet seed, (a) 30×, (b) 100×; (c-e) conidia and conidiophore, (c & e) 1000×, (d) 250×.

DARARAMAN 1922, OCFEEMIA 1924, TUCKER 1927, PADMANABHAN et al. 1948, BEDI & GILL 1960). It is considered to be a major factor contributing to the Bengal famine of 1942 (GHOSE et al. 1960).

Occurrence: The species was mainly recorded on seeds of rice, but trace infection in wheat and sorghum were also observed. Analysis of 668 rice samples is given in table 1.

TABLE 1.
Infection of *Drechslera oryzae* in rice seed samples observed during 1967-71.

Country	Total no. of samples	Samples infected	Infection percentage	
			Min.	Max.
Nigeria	233	193	0,3	58,8
Thailand	139	119	0,3	52,3
Nepal	91	85	0,3	73.0
India	60	48	0,3	52.0
Indonesia	32	31	1,8	90.8
Korea	27	27	10.0	39.0
Philippines	36	24	0,3	29.3
Egypt	20	20	1,8	35.5
Ghana	7	7	0,8	50.0
S. Vietnam	5	4	1.0	10.0
Ceylon	5	5	4.0	11.5
Iran	5	5	0,8	54.8
Japan	4	1	1.0	—
Portugal	3	3	5.0	12.8
Pakistan	1	1	7.0	—
Total	668	573		

15. **Drechslera rostrata** (DRECHS.) RICHARDSON & FRASER

Helminthosporium rostratum DRECHS.
Bipolaris rostrata (DRECHS.) SHOEM.
Drechslera rostrata (DRECHS.) SUBRAM.
(Plate 16)

On seed: The growth characters on seed are similar to *Drechslera halodes* and *D. longirostrata,* but the conidia are straight or slightly curved, rostrate, shorter and broader than *D. longirostrata,* dark end septa visible.

Conidia (under compound microscope): Olivaceous to dark brown, ellipsoid to rostrate, broadest in or about the middle, end septa darker and thicker, hilum protuberant, 13.6-153.0 × 13.6-23.8 μ, 3-13-septate.

Economic importance: The species was first described from leaf spot of *Eragrostis major* (Drechsler 1923). It has been recorded on sorghum from United States, Ghana, Israel and Sudan and is fairly widespread in soils of Georgia, U.S.A. Hybrid maize seed in Texas showed 85 per cent infection on PDA which had only 15 per cent viability (Tarr 1962). The infected kernels of maize show pink discoloration (Whitehead & Calvert 1959).

Occurrence: The fungus was recorded on seeds of *Althaea rosea, Beta vulgaris, Brachiaria ruziziensis, Calendula officinalis, Capsicum annuum, Cenchrus ciliaris, Chloris gayana, Coriandrum sativum, Cuminum cyminum, Eleusine coracana, Linum marginale, Luffa acutangula, Momordica charantia, Oryza sativa, Pennisetum glaucum, Phaseolus aureus, P. mungo, Sesamum indicum, Setaria italica, Solanum melongena, Sorghum bicolor, S. vulgare, Tagetes* sp. *Triticum aestivum, Verbena* sp., *Vigna sinensis,* and *Zea mays.*

16. **Drechslera sacchari** (Butl.) Subram. & Jain

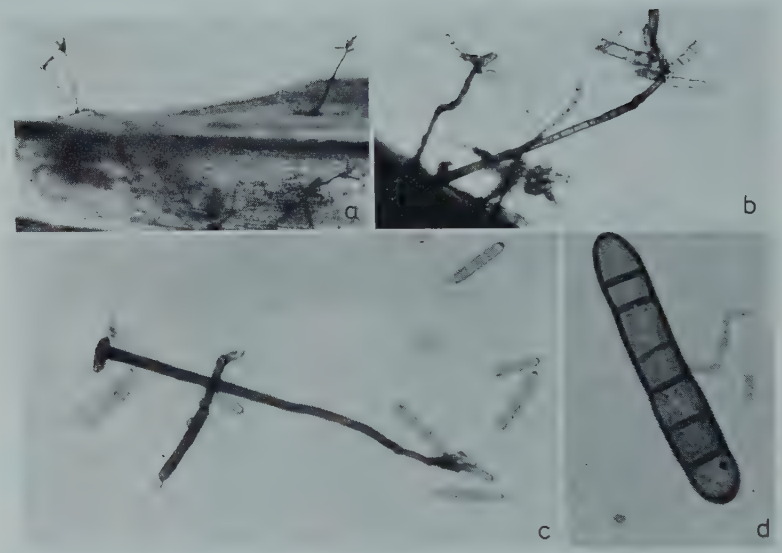
Helminthosporium sacchari Butl.
Bipolaris sacchari (Butl.) Shoem.
(Plate 17)

On seed: Conidiophores light brown, single or in groups of 2 to 4 bearing conidia at shorter intervals than *Drechslera maydis.* Conidia acropleurogenous, dark brown, mostly straight or slightly curved.

Conidia (under compound microscope): Olivaceous brown, mostly straight or slightly curved, broader in the middle, ends rounded, hilum broad, clear and within the contour, 25.5-115.6 × 8.5-15.3 μ, 4-11-septate.

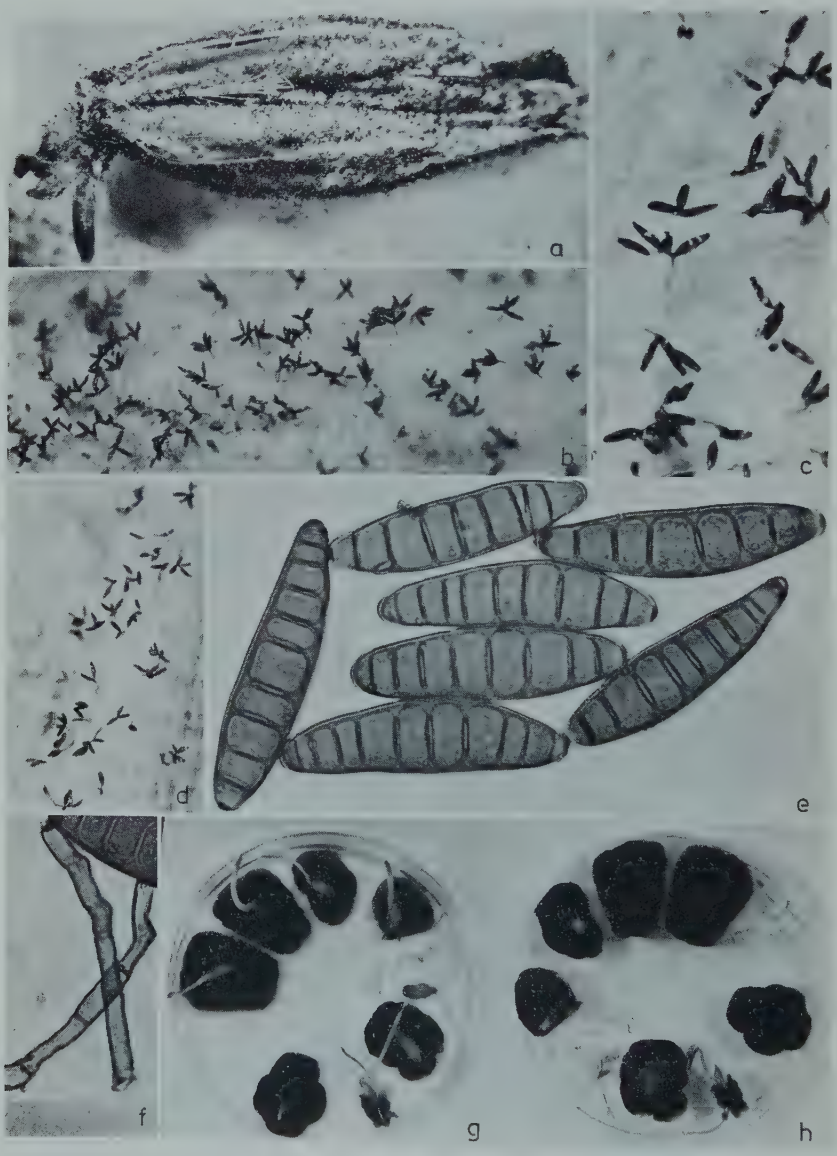
Economic importance: In 1956, Loveless & Smith reported that the fungus was responsible, especially in very humid condition, for the death of germinating seedlings and proposed that the disease might be called 'eye spot and seedling blight' of sugar cane; widespread (CMI map No. 349, 1968). Luttrell (1954) observed the fungus being associated with the blackening of individual grains, and leaf spots in pearl millet.

Drechslera sacchari. (a-e) on pearl millet seed, (a) 30×, (b-c) 50×, (d-e) 100×; (f) conidia and conidiophores—250×; (g) lighter tip of conidiophore—1000×; (h) conidia—1000×.



Drechslera siccans. (a-b) on rye grass seed, (a) 50×, (b) 250×; (c-d) conidia and conidiophores, (c) 250×, (d) 1000×.

Drechslera sorghicola. (a-b) on sorghum seed—100×; (c-d) conidia and conidiophores—1000×; (e-f) colonies on PDA, (e) top view and (f) reverse view.



Drechslera sorokiniana. (a-b) on barley seed, (a) 15 × and (b) 50 ×; (c) on soybean—100 ×; (d) on rice—50 ×; (e-f) conidia and conidiophores—1000 ×; (g-h) colonies on PDA, (g) top view and (h) reverse view.

Occurrence: It was recorded only on seeds of *Pennisetum glaucum.*

17. **Drechslera siccans** (Drechs.) Shoem.

Helminthosporium siccans Drechs.
(Plate 18)

On seed: Conidiophores dark brown to almost black, long erect, typically bulbous at base. Conidia acropleurogenous 2 to 7, perpendicular to the axis, form compact or loose clusters, fuliginous to light brown, cylindrical with rounded ends.

Conidia (under compound microscope): Fuliginous to yellowish brown, cylindrical with rounded ends, broad scar at the base, 54.4-112.2 × 13.6-15.3 μ, 4-6-septate.

Economic importance: Causes foot rot and leaf spot mainly on several cultivated species of *Lolium* in North America and Europe (Dickson 1956).

Occurrence: The species was observed on seeds of *Avena sativa, Bromus unioloides, Festuca arundinacea, F. pratensis, Hordeum vulgare,* and *Lolium perenne.*

18. **Drechslera sorghicola**
(Lefevre & Sherwin), Richardson & Fraser

Helminthosporium sorghicola Lefevre & Sherwin
(Plate 19)

On seed: Conidiophores dark brown or black, single or in groups, short to medium. Conidia acropleurogenous, olivaceous to dark brown, ellipsoid, straight or slightly curved; short secondary conidiophores with 1-2 conidia common.

On agar: Top view: Colonies smooth, powdery, olivaceous brown, dark towards the edges, margin irregular.

Reverse view: Colonies medium, black in the centre, olivaceous brown with a slight green tinge in the peripheral zone, rough, margin irregular. In few cases margins smooth with lighter edges. Concentric rings visible. Mycelium feathery, radiating or fern like.

Conidia (under compound microscope): Fuliginous to olivaceous brown, ellipsoid, straight or slightly curved, broader in the

middle, gradually tapering towards the rounded ends; scar broad, conspicuous in few cases, 49.4-85.0 × 11.9-15.3 μ, 6-8-septate.

Economic importance: Causes target spot in *Sorghum vulgare, S. sudanense,* and *S. halepense* in the United States, Sudan, Israel, India, and Cyprus (TARR 1962).

Occurrence: The species was observed only on seeds of *Sorghum vulgare.*

19. **Drechslera sorokiniana** (SACC.) SUBRAM. & JAIN

Helminthosporium sorokinianum SACC.
Bipolaris sorokiniana (SACC.) SHOEM.
Helminthosporium sativum PAMM., KING & BAKKE
Helminthosporium californicum MACKIE & PAXTON
Perfect state: *Cochliobolus sativus* (ITO & KURIB.) DRECHS. ex DASTUR
(Plate 20)

On seed: Conidiophores brown, short, erect, in most cases single, bearing 1-6 conidia acropleurogenously at short distances in the upper half. Conidia dark brown to black, shiny (characteristic of this species), oblong to ellipsoid.

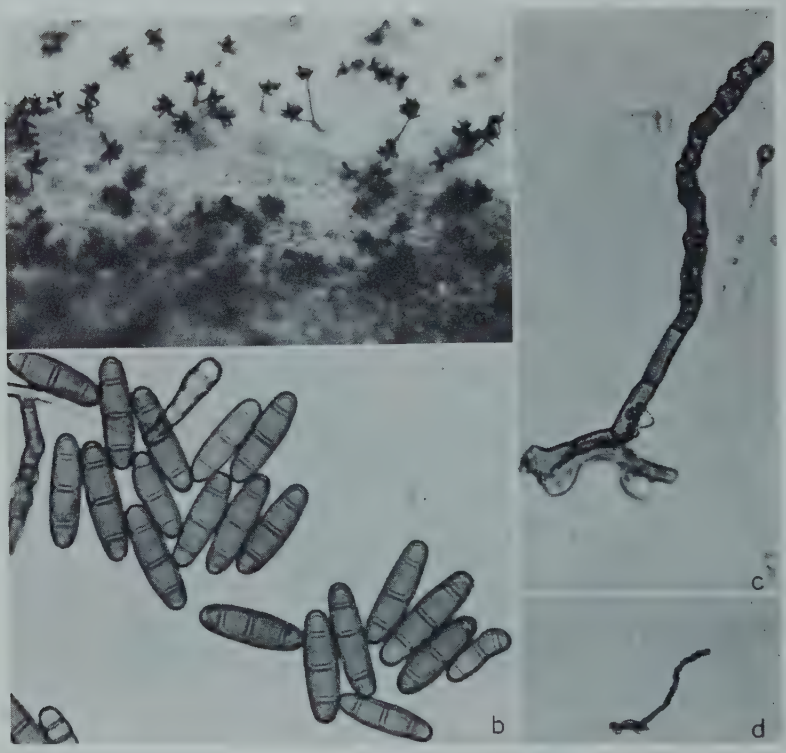
On agar: Top view: Colonies olivaceous brown to very dark becoming generally lighter towards the periphery, margin mostly smooth, sometimes wavy with easily recognizable dark band; large number of conidia usually present in the centre; sometimes entire colony covered by black shiny conidia making the colony black and shiny, rarely colonies pinkish white with almost no conidia.

Reverse view: Colonies black to deep olivaceous brown, roughly circular with concentric rings, margin smooth or irregular; rarely colonies light pinkish white.

Conidia: (under compound microscope): Ellipsoid, dark brown, mostly straight or slightly curved, wall thick but less so towards the ends, broadest in the middle, ends rounded, scar clear within the basal cell. Terminal portion of the end cells subhyaline, 68.0-98.6 × 17.0-23.8 μ, 6-9-septate.

Economic importance: Wide spread (CMI map No. 322, 1967), and with a wide host range causing black point, seedling blight, root rot and blotch of quack grass, oats, brome grass, barley wheat etc. (NOBLE & RICHARDSON 1968), leaf spot of snap bean (GOURLEY 1968), mostly common in wheat and barley (DICKSON 1956). Recently it has been reported to cause leaf spots on rice in

Drechslera teres. (a-b) on barley seed—100×; (c-d) conidia and conidiophores, (c) 250×, (d) 1000×.



Drechslera tetramera. (a) on dill seed—100 ×; (b) conidia—1000 ×; (c-d) conidiophores, (c) 1000 ×, (d) 250 ×.

New South Wales, Australia (Anonymous 1966-1967, 1969, Walker et al. 1968). In western Europe it infects spring sown cultivars of barley, but not causing any serious injury (De Tempe 1964). In the blotter test, this species has been found associated with the browning of roots in barley seedlings.

Occurrence: The species was encountered on seeds of *Agropyron elongatum, Avena sativa, Brachiaria ruziziensis, Bromus unioloides, Calendula officinalis, Capsicum annuum, Chrysanthemum cinerariifolium, Coriandrum sativum, Cucurbita pepo, Cuminum cyminum, Daucus carota, Glycine max, Helianthus annuus, Hordeum vulgare, Oryza sativa, Pennisetum glaucum, Phaseolus vulgaris, Raphanus sativus, Sesamum indicum, Setaria italica, Sorghum vulgare, Triticum aestivum,* and *Vigna sinensis.*

20. **Drechslera teres** (Sacc.) Shoem.

Helminthosporium teres Sacc.
Perfect state: *Pyrenophora teres* Drechs.
(Plate 21)

On seed: Conidiophores dark brown to blackish, straight, medium, arising singly in most cases, conidia acropleurogenously borne at wider distances. Conidia lighter than conidiophores, cylindrical, septa visible. In few cases under ordinary conditions and in many cases on the frozen seeds, secondary conidiophores or conidiophore-like protrusions bear one to three olivaceous conidia.

Conidia (under compound microscope): Fuliginous to light olivaceous brown, straight cylindrical, normally basal cell inflated, in few cases basal cells longer than wide, scar clear, 32.3-100.3 × 13.6-18.7 μ, 1-5-septate.

Economic importance: Causes net blotch of barley which is widespread throughtout Europe, North America, East Africa (CMI map No. 364, 1968). Kenneth (1962) observed *Dreschlera teres* becoming increasingly serious on barley in Israel. In Argentina the fungus infected susceptible cultivars of barley up to 80 per cent and caused high infection rates (Tessi & Rodriguez 1961, Rodriguez & Frecha 1962). Net blotch is the most common barley disease in West Australia (Anonymous 1961). Recently Smedegård-Petersen (1971) reported the occurrence of spot blotch due to this fungus on

barley in Denmark and made a new form, *D. teres* (Sacc.) Shoem. forma *maculata* Smedegård-Petersen.

Occurrence: The species was recorded only in seeds of *Hordeum vulgare.*

21. **Drechslera tetramera** (McKinney) Subram. & Jain

Helminthosporium tetramera McKinney
Bipolaris tetramera (McKinney) Shoem.
(Plate 22)

On seed: Conidiophores brownish, single or in clusters of 2 to 3. Conidia acropleurogenous at short intervals, almost in cluster, short, light to dark brown, ellipsoid to almost cylindric with rounded ends, perpendicular to the axis.

Conidia (under compound microscope): Brown, ellipsoid, mostly cylindric, straight with broadly rounded ends, lighter towards the terminal cells, 20.4-35.7 × 8.5-13.6 μ, 3-septate.

Economic importance: The species was first described causing foot rot in winter wheat (McKinney 1925). It is reported to cause crown and root rot disease and leaf spot in *Trapa bispinosa* and *Crotalaria juncea* (Singh & Lal 1965, Naphade 1968) and storage disease of *Capsicum annuum* (Rao 1967).

Occurrence: The species was observed on seeds of many crops: *Agropyron elongatum, Allium cepa, Althaea rosea, Anethum graveolens, Antirrhinum majus, Beta vulgaris, Brassica oleracea* var. *botrytis, B. oleracea* var. *capitata, Bromus unioloides, Calendula officinalis, Capsicum annuum, C. frutescens, Carthamus tinctorius, Cenchrus ciliaris, Cheiranthus cheiri, Chloris gayana, Chrysanthemum cinerariifolium, Citrullus vulgaris, Corchorus capsularis, Coriandrum sativum, Cucumis melo, C. sativus, Cucurbita pepo, Cuminum cyminum, Dahlia variabilis, Datura innoxia, D. stramonium* var. *inermis, Daucus carota, Delphinium ajacis, Dianthus caryophyllus, Dolichos lablab, Eleusine coracana, Festuca arundinacea, Foeniculum vulgare, Glycine max, Helianthus annuus, Hibiscus cannabinus, H. sabdariffa, Hordeum vulgare, Hyoscyamus niger, Iberis amara, Linum marginale, Lycopersicon esculentum, Mathiola incana, Oryza sativa, Panicum miliaceum, P. miliare, Papaver somniferum, Pennisetum glaucum, Petroselinum sativum, Phaseolus aureus, P. mungo, P. vulgaris, Phlox drummondii, Pimpinella anisum, Pisum sativum, Raphanus sativus, Sesamum indicum, Setaria italica, Solanum melongena, Sorghum vul-*

Drechslera tuberosa. (a) on *Chrysanthemum cinerariifolium* seed—50×; (b) on oat seed—50×; (c) conidia—250×; (d-e) conidia—1000×.

Drechslera turcica. (a-b) on sorghum seed—100×; (c-d) conidia and conidiophores, (c) 1000× and (d) 250×.

gare, Tagetes sp., *Triticum aestivum, Verbena* sp., *Vicia faba, Vigna sinensis,* and *Zea mays.*

22. **Drechslera tuberosa** (Atk.) Shoem.

Helminthosporium tuberosum Atk.
Drechslera japonica (Ito & Kurib.) Shoem.
Helminthosporium japonicum Ito & Kurib.
Perfect state: *Pyrenophora japonica* Ito & Kurib.
(Plate 23)

On seed : Conidiophores light to dark brown, short to medium, sometimes long, single; secondary conidiophores common. Conidia long, cylindric, acropleurogenous, fuliginous brown, secondary conidiohpores bear 2-3 conidia. Growth very similar to that of *Drechslera teres,* but secondary conidiophores and conidia common even under normal incubation conditions in *D. tuberosa.*

Conidia (under compound microscope): Olivaceous brown, broad, cylindric, long, slightly tapering just above the middle in some cases; basal cell longer than wide, scar wide and clear, 32.3-122.4 × 11.9-20.4 μ, 2-7-septate.

Economic importance: This species causes leaf spots in a number of grasses, rye and barley; importance of seed transmission is not known.

Occurrence: The species was recorded on seed of *Avena sativa, Chrysanthemum cinerariifolium,* and *Triticum aestivum.*

23. **Drechslera turcica** (Pass.) Subram. & Jain

Helminthosporium turcicum Pass.
Bipolaris turcicum (Pass.) Shoem.
Perfect state: *Trichometasphaeria turcica* Luttrell
(Plate 24)

On seed: Conidiophores light to dark brown, medium to long, sometimes very long, flexuous, broad, geniculate, arising in groups of 2 or more. Conidia fusoid, straight or slightly curved, light to dark brown, acropleurogenous. If looked carefully under the binocular microscope the fusoid conidia are attached to the conidiophores in a loose way due to protuberant hilum and obconic and narrow base can be seen.

Conidia (under compound microscope): Yellowish brown, fusoid, straight or slightly curved, widest near the middle, tapering

towards ends, apex rounded, basal cell conical ending in a protuberant hilum, 96.9-125.8 × 17.0-22.1 μ 4-7-septate.

Economic importance: Causes leaf blight of *Zea mays, Sorghum vulgare, S. sudanense,* and *S. halepense* (Tarr 1962), widespread both in tropical and subtropical areas, viz. U.S.A., part of South America, most of the African countries, Southern Europe, India, Pakistan, Iran, U.S.S.R., South-East Asian countries, Australia etc. (CMI map No. 257, 1968). *Drechslera turcica* which infects maize may be a different physiologic race (Noble & Richardson 1968).

Occurrence: The species was observed in seeds of *Sorghum bicolor* and *S. vulgare.*

24. **Drechslera urochloae** (Puttrill) Subram. & Jain

Helminthosporium urochloae Putterill
Bipolaris urochloae (Putterill) Shoem.
(Plate 25)

Onseed: Growth similar to that of *Drechslera bicolor* (Plate 2). Conidiophores light to dark brown, slender, mostly short, few medium. Conidia dark brown, almost black, shiny, long, ellipsoid, straight or curved, tapering towards the ends, acropleurogenous.

Conidia (under compound microscope): Dark brown, long, slender, straight, curved or sigmoid, uniformly narrowing towards the ends, apex rounded, base ending in a clear, flat, dark scar, 39.1-171.7 × 10.2-18.7 μ, 2-13-septate.

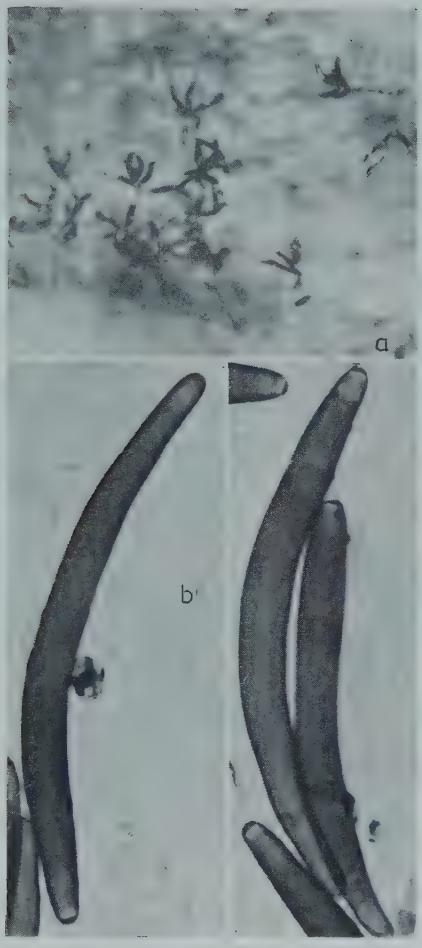
Economic importance: Putterill (1954) described the species from *Urochloa helopus* and suspected it to be the possible cause of eye spot disease.

Occurrence: The species was observed only on a single seed of *Sorghum vulgare.*

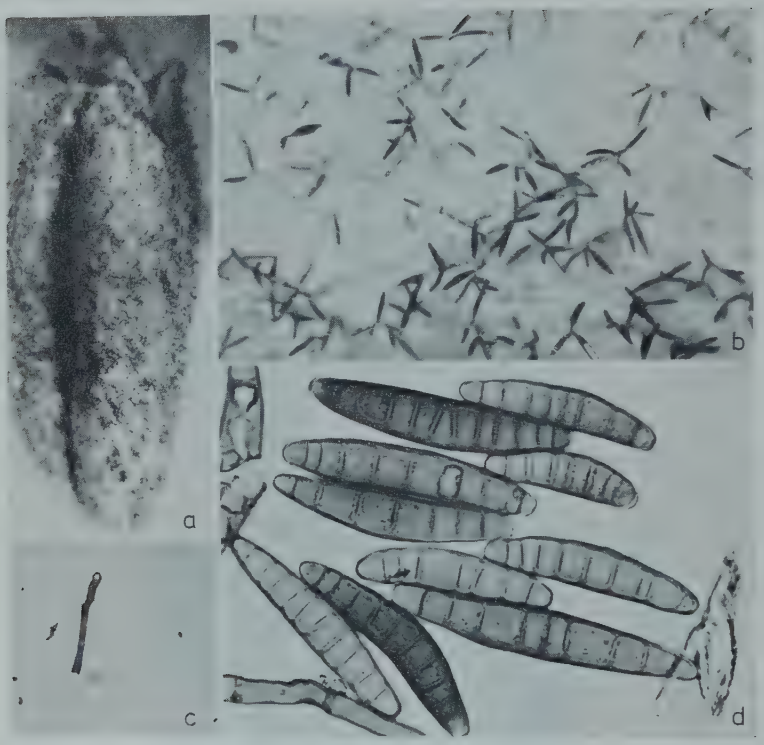
25. **Drechslera victoriae** (Meehan & Murphy) Subram. & Jain

Helminthosporium victoriae Meehan & Murphy
Bipolaris victoriae (Meehan & Murphy) Shoem.
(Plate 26)

Onseed: The growth characters on seed very similar to those of *Drechslera sorokiniana* (Plate 20) except in this case the conidia little lighter in colour, slender and slightly curved.



Drechslera urochloae. (a) on sorghum seed—100×; (b) conidia—1000×.



Drechslera victoriae. (a-b) on wheat seed, (a) 15×, (b) 100×; (c) conidiophore—250×; (d) conidia—1000×.

Conidia (under compound microscope): Long, ellipsoid, straight or slightly curved, thin walled, fuliginous to olivaceous dark brown, 25.7-107.1 × 10.2-16.1 μ, 5-12-septate.

Economic importance: Causes the destructive blight of oats with Victoria parentage bred in North America. Weakly parasitic on *Agropyron cristatum, Chloris gayana, Dactylis glomerata, Phleum pratense, Setaria virides, barley, sorghum* and *soybean* (MEEHAN & MURPHY 1946). It is mostly prevalent in North America, Australia, Brazil, Netherlands, and Switzerland (CMI map No. 267, 1968). TVEIT (1956) observed the species in oat seed samples from South America.

Occurrence: The species was recorded only on seed of *Triticum aestivum.*

DISCUSSION

Drechslera ITO. *(Bipolaris* SHOEM., *Helminthosporium* LINK. pro parte) is an important genus having a large number of pathogenic species, which are mainly restricted to the *Gramineae.* Identification, host range and economic significance of different species has been studied by many workers in different parts of the world (RAVN 1900, 1901, DRECHSLER 1923, NISIKADO 1928, MITRA 1931, PUTTERILL 1954, SHOEMAKER 1957, 1962, LUTTRELL 1957, 1969, KENNETH 1958, 1962, BRAVERMAN & GRAHAM 1960, RANGASWAMY & PANDURANGAN 1962, MÄKELÄ 1971, ELLIS 1971). Many of these species are seed-borne and seed-transmitted causing seed rot, foot rot, seedling blight, blotch, stripe, leaf and head blight. So far habit characters of only few of the seed-borne species have been studied and described. The first such comprehensive publication was that of DE TEMPE (1964) from Holland who described diagnostic growth characters of *Drechslera avenae, D. graminea, D. sorokiniana, D. teres,* and *D. victoriae* on blotters and agar. A few such as *D. avenacea, D. avenae, D. graminea, D. oryzae, D. siccans,* and *D. teres* were studied by the Plant Disease Committee of International Seed Testing Association and results published by NOBLE (1966). MALONE & MUSKETT (1964) described fungi encountered in oat seeds including three species of *Drechslera.*

Diagnostic growth characters of 25 species of *Drechslera* observed on seeds of temperate and tropical crops in the blotter test have been described and illustrated in this paper. A number of them can be easily identified under the stereobinocular microscope by trained seed

GROWTH CHARACTERS OF DRECHSLERA AND THEIR CONIDIA

(Magnification: Growth on seed 270x; conidia 1000x.)

GROUP 1.

Fig. 1. Drechslera maydis

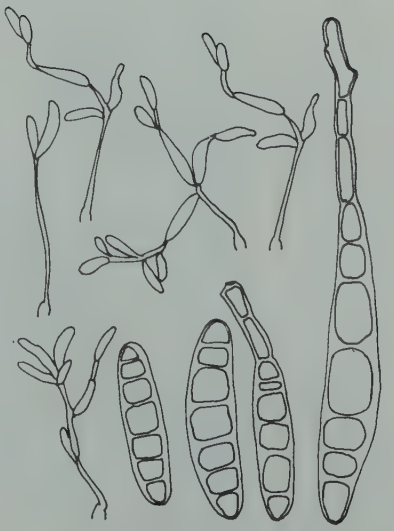


Fig. 2. Drechslera sorghicola

analysts without examining the conidia in compound microscope. Knowledge of the host seed does help in their identification, but it has been seen that some species may develop on seeds of "non-host" crops, and others may have a wide host range. The growth of a few species may appear alike under the low power stereobinocular microscope. It is then advisable to make slides and examine the conidia under high magnification of the compound microscope before identification. Based on the similarities in the nature of conidiophores, and shape and colour of conidia, the investigated 25 species of *Drechslera* can be placed in the following 8 groups:

Group 1. *Drechslera maydis, D. sorghicola* and *D. oryzae.*
(Figs. 1-3)

All the three species have curved conidia which appear yellowish to olivaceous brown. The curvature is particularly conspicuous in *D. maydis* which usually has long, slender, flexuous conidiophores. In some forms of this species the conidiophores are rather short resembling those of the other two species. Even in such forms the nature of conidia makes it possible to distinguish it from the other two species. The conidia of *D. oryzae* are comparatively less curved, broader and a little darker. Under the compound microscope, the conidia of *D. maydis* are strongly curved tapering sharply towards ends, with a flat base and a more or less inconspicuous hilum. In *D. oryzae* the curvature is not so strong, ends are rounded, and the base may be papillate. The conidia of *D. sorghicola* are the least curved, they are small and the species can easily be distinguished by formation of secondary conidiophores and conidia, a feature that often is easily detectable under stereobinocular microscope.

The identification of the three species on agar appeared to be rather easy. Colonies of both *D. maydis* and *D. oryzae* are fast growing and fluffy, the former, however, was found commonly to have concentric rings which were absent in the latter. *D. sorghicola* produces colonies which are much darker, smooth, powdery with feathery radiating mycelium.

D. sacchari can also be placed in this group because it looks more or less similar to *D. sorghicola* on seeds under stereobinocular microscope (Fig. 4). Although its conidia have the general appearance of *D. maydis* and *D. oryzae,* they can still be distinguished as they are

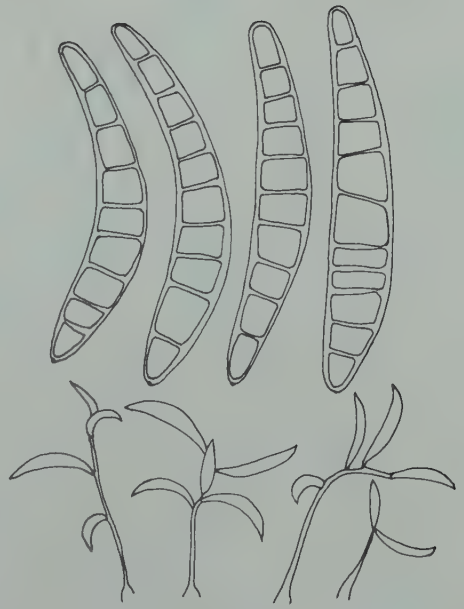


Fig. 3. Drechslera oryzae

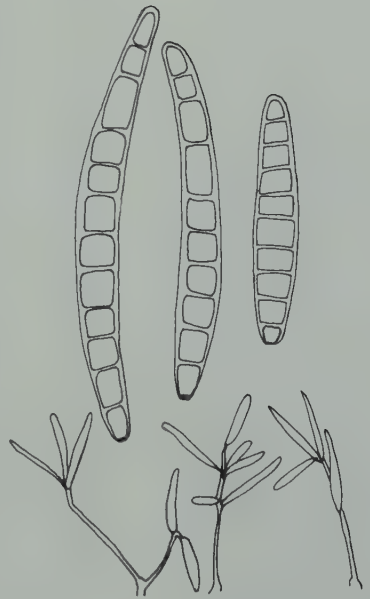


Fig. 4. Drechslera sacchari

generally more straight to only slightly curved. The dark scar in the basal cell of the conidium is very conspicuous under the compound microscope.

Group 2. *Drechslera sorokiniana, D. victoriae, D. bicolor,* and *D. urochloae.*

(Figs. 5-8)

The criteria for grouping these species are the dark brown to black or blackish brown shiny colour of conidia and the short to medium conidiophores. The shape of the conidia is the main distinguishing character. They are short, ellipsoid, almost straight in *D. sorokiniana,* slender, slightly curved in *D. victoriae,* cylindric to long ellipsoid, straight or slightly curved in *D. bicolor,* and long, slender, curved or more rarely sigmoid in *D. urochloae.* The conidiophores are short and slender in *D. sorokiniana* and *D. victoriae* and medium and comparatively broader in *D. bicolor* and *D. urochloae.*

Under the compound microscope the conidia of *D. sorokiniana* are short, ellipsoid, dark brown, mostly straight and thick walled while *D. victoriae* has slender, slightly curved, light, thin-walled conidia. The end cells in *D. bicolor* are little lighter and sometimes the end septa are dark and thick whereas the conidia of *D. urochloae* are long, slender and straight or curved, uniformly narrowing to both ends with a flat base and a dark scar.

In agar *D. sorokiniana* produces a characteristic black restricted colony with a dark, peripheral, wavy band. Only in one seed sample few colonies were not restricted, and the mycelium was of the spreading type almost devoid of concentric rings. *D. bicolor* was found to be quite variable in the agar test and it is very difficult to fix a definite character. Due to the lack of sufficient seed material *D. urochloae* and *D. victoriae* were studied only in pure culture. *D. urochloae* behaved like *D. bicolor* on sorghum from Botswana. In *D. victoriae* the difference in culture was so slight that no definite line can be drawn between them on this basis.

Group 3. *Drechslera halodes, D. rostrata* and *D. longirostrata.*

(Figs. 9-11)

The distinguishing characters for these three species are only the shape and relative lenght of their conidia.

GROUP. 2.

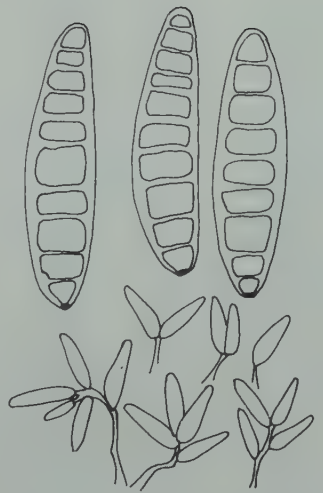


Fig. 5. Drechslera sorokiniana

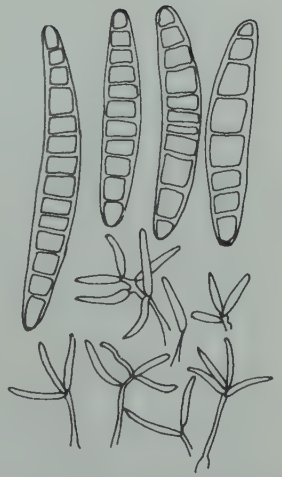


Fig. 6. Drechslera victoriae

Fig. 7. Drechslera bicolor

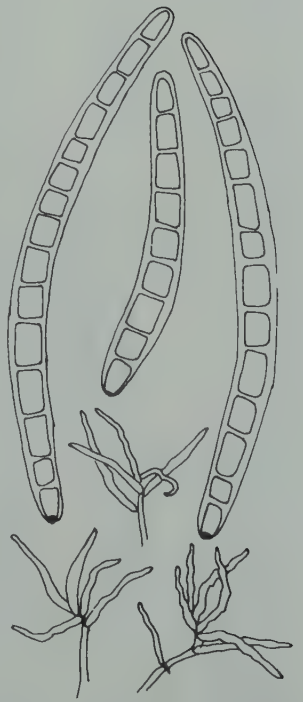


Fig. 8. Drechslera urochloae

Fig. 9. Drechslera halodes

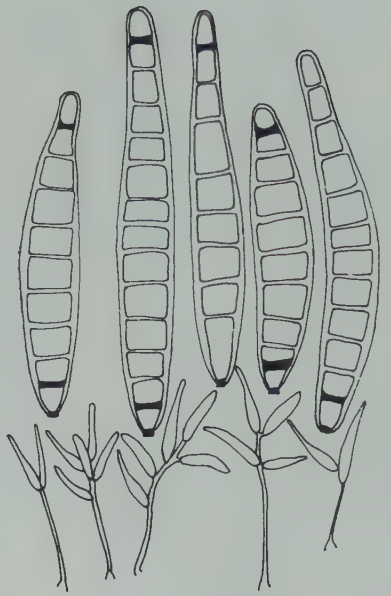


Fig. 10. Drechslera rostrata

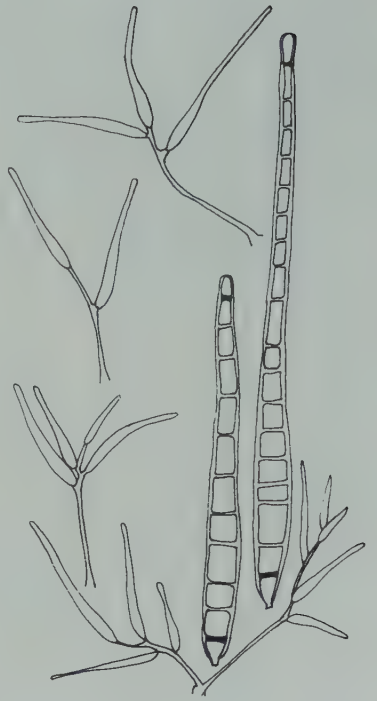


Fig. 11. Drechslera longirostrata

GROUP. 4.

Fig. 12. Drechslera tetramera

Fig. 13. Drechslera hawaiiensis

Fig. 14. Drechslera dematioidea

The conidia of *Drechslera halodes* are ellipsoid or almost cylindric (never rostrate), fuliginous or dark brown. *D. rostrata* can be easily identified by the medium size rostrate conidia in which often the dark end septa are visible in the stereobinocular while *D. longirostrata* is generally differentiated by the presence of long, slender, rostrate conidia where in some cases the apical cell is inflated. The ellipsoid conidia of *D. halodes* may in some cases look like those of *D. sorokiniana,* but its conidiophores are longer and the end septa are dark and thick, a characteristic which in many cases is seen clearly under the stereobinocular.

SUBRAMANIAN stated that the maximum lenght, mean length, mean width, and the length/width ratio can be used as criteria in separating species having rostrate conidia. Based on these characters only, he described *Helminthosporium longirostratum* SUBRAM. in 1956. In most cases we have recorded this species based on its characters on seeds. Sometimes we encountered colonies in which some conidia were very long of the type of *D. longirostrata* and some short like those of *D. rostrata.* We have always taken into consideration the length of the majority of the spores in assigning the species name. But this may not hold good in all cases as there is every possibility of the long spored forms becoming short or vice versa. SUBRAMANIAN (1956)

TABLE 2.

Data on conidia of two selected isolates of *D. longirostrata* from seed as well as from PDA.

Characters	*D. longirostrata*			
	Isolate from *Sorghum*		Isolate from *Oryza*	
	on seed	PDA	on seed	PDA
Maximum length	316.8	198.0	178.2	293.0
Minimum length	51.0	39.1	93.5	85.0
Mean length	190.4	96.6	126.4	154.9
Maximum width	19.8	17.0	15.3	15.3
Minimum width	11.9	13.2	13.2	13.2
Mean width	16.0	14.5	14.0	13.8
Maximum septa	20	15	12	22
Minimum septa	7	4	9	8
Mean septa	13.2	8.7	10.5	12.5
Length/width	11.9	6.6	9.0	11.2

GROUP. 5.

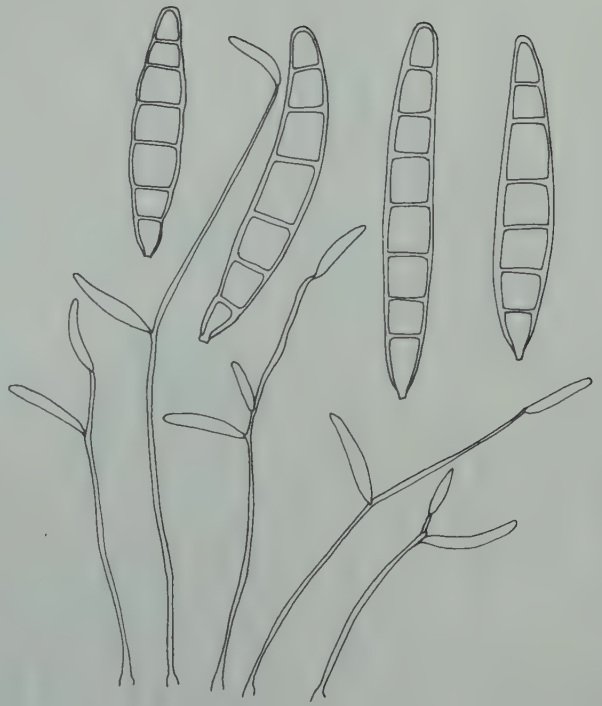


Fig. 15. Drechslera turcica

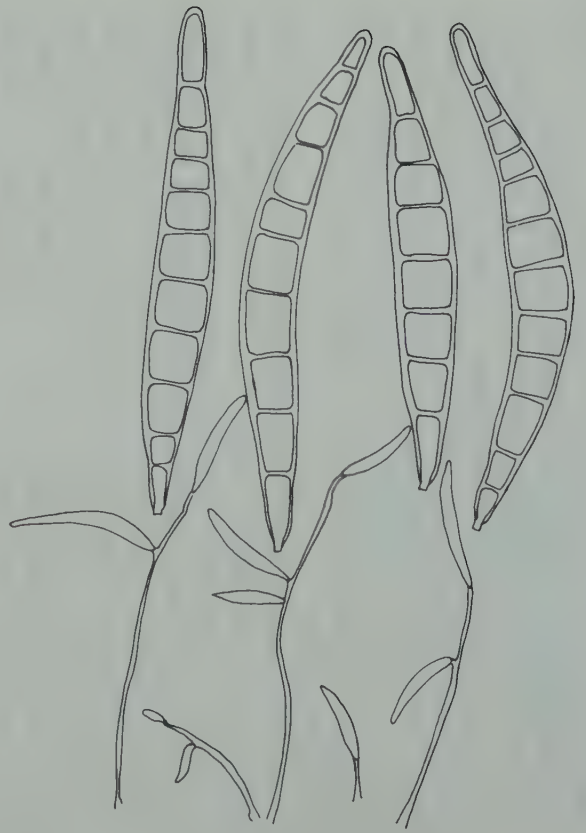


Fig. 16. Drechslera monoceras

discussed these aspects based on the characters of single isolate of each species which he tried on four different media. Detailed observations were made on two isolates of *D. longirostrata* and the results are included in Table 2.

The isolates from *Sorghum* produced shorter conidia in culture than those produced on host material, while the isolate from *Oryza* produced longer conidia in culture. Taking into consideration such a variation in conidial length from host to culture, it seems unnecessary to separate species based on conidial length only. Further studies based on a large number of isolates should be carried out to substantiate the position of *D. longirostrata*.

Group 4. *Drechslera tetramera, D. hawaiiensis,* and *D. dematioidea.*
(Figs. 12-14)

The arrangement of conidia on conidiophores and shape of conidia are the common characters in the three species of this group. *Drechslera tetramera* is characterized by the presence of long and compact clusters of conidia towards the apices of the conidiophores and the conidia are generally placed nearly perpendicular to the axis of the conidiophores. They are broad and more or less uniform in size. In *D. hawaiiensis* the conidia are slender and show much variation in size and shape and may point out in all directions. *D. dematioidea* differs from the two species in not having closely packed clusters of conidia; the conidia are broader towards the tip narrowing down to the point of attachment.

Under the compound microscope the conidia of *D. tetramera* appear regularly 3-septate, almost cylindric, the end cells having subhyaline areas towards their terminal portions. Conidia of *D. hawaiiensis* are cylindric or cylindroclavate with 4 or more septa. Conidia of *D. dematioidea* are 3 to 5-septate, broader at the top tapering towards the base, ending in a wide scar.

Group 5. *Drechslera turcica* and *D. monoceras.*
(Figs. 15-16)

Since the two species resemble each other so much, it was often found difficult to distinguish one from the other. The conidia of the two species are fusoid narrowing towards both ends. Tapering of

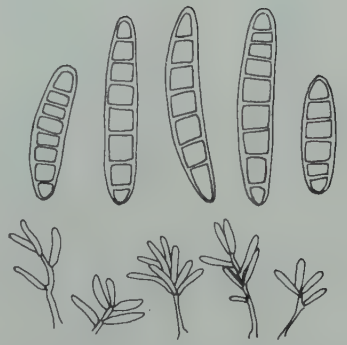


Fig. 17. Drechslera cynodontis

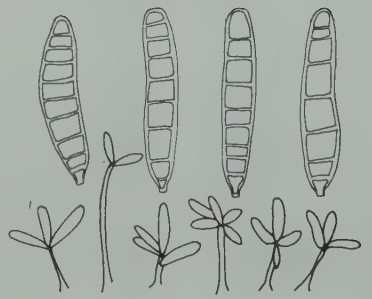


Fig. 18. Drechslera micropa

conidia towards the apex and the base in the case of *Drechslera monoceras* is sharper than in *D. turcica*. Both species have protruding hilum but the protusion is more distinct in *D. monoceras*. This feature along with the long, narrow conical basal cell and curvature in the middle of the conidia makes the conidia appear to hang down. This character separates *D. monoceras* from *D. turcica*.

Group 6. *Drechslera cynodontis* and *D. micropa*.
(Figs. 17-18)

Although the two species are not closely related in details of morphology of conidia, they appear to some extent alike on the seeds under stereobinocular microscope. The conidia of *D. micropa* have a small protruberant hilum, while in *D. cynodontis* the hilum has a dark scar within the contour of the basal cell.

Group. 7. *Drechslera siccans, D. avenae, D. teres, D. graminea* and *D. tuberosa*.
(Figs. 19-23)

All the species in this group have in common cylindrical conidia and four of them, *Drechslera avenae, D. graminea, D. teres,* and *D. tuberosa* show more or less similar growth on seeds under stereobinocular microscope. However, *D. siccans* and *D. avenae* are usually non-catenate while the others are catenate. *D. siccans* can easily be identified by its long, straight, dark conidiophores having bulbous base. The conidia are compactly arranged at apices of conidiophores (Fig. 19). The conidiophores of *D. avenae* appear zigzag bearing individual conidia at long distances on the geniculate bends.

Amongst the catenate types *D. graminea* and *D. teres* are generally seed-borne in barley and their identification is rather difficult when they are present as mixed infections in the same seed lot. *D. teres* produces comparatively long, cylindrical conidia which are lighter than the conidiophores. Chains of conidia are not common in routine blotter tests, but when present, they consist of 2 or 3 conidia in simple straight chains which may arise simultaneously from the tip of a single conidium (Fig. 21). Usually the general growth pattern of *D. graminea* is the same as that of *D. teres*. However, catenation is common in *D. graminea* where chains of 2 to 3 in the blotter test are usually formed. The number in each chain may increase up to 6 or 7

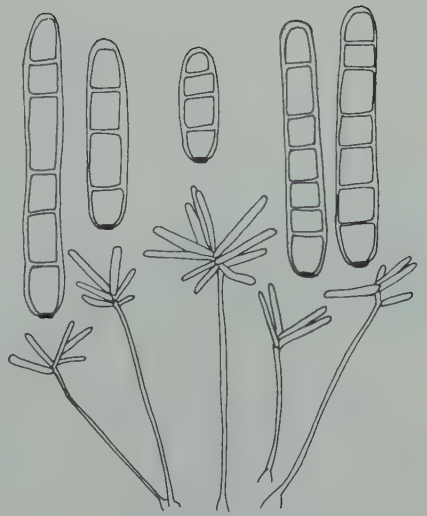


Fig. 19. Drechslera siccans

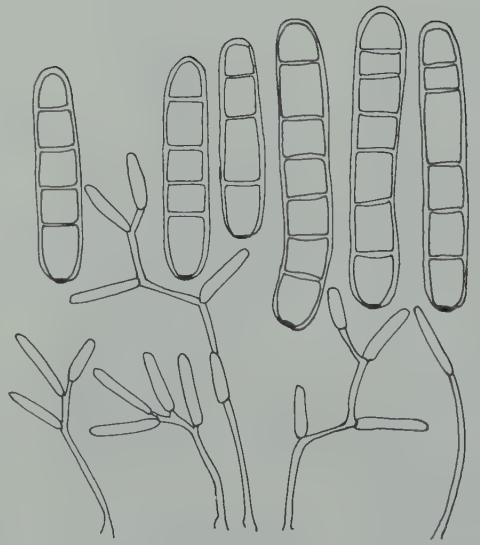


Fig. 20. Drechslera avenae

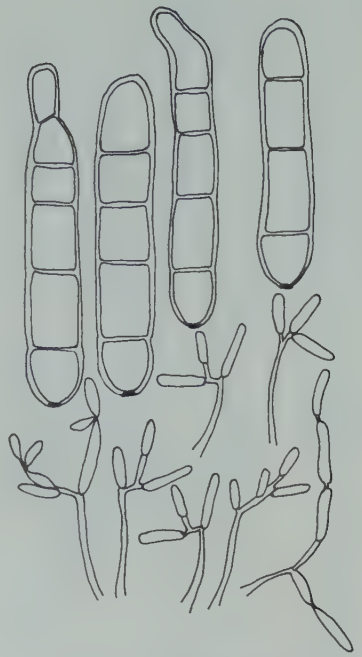


Fig. 21. Drechslera teres

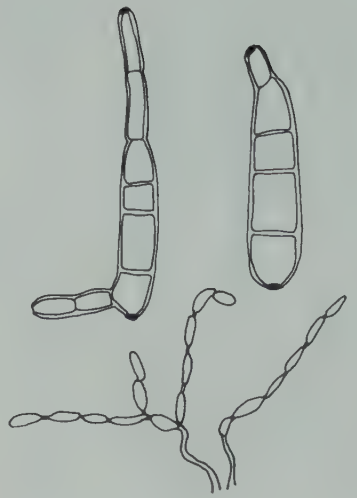


Fig. 22. Drechslera graminea

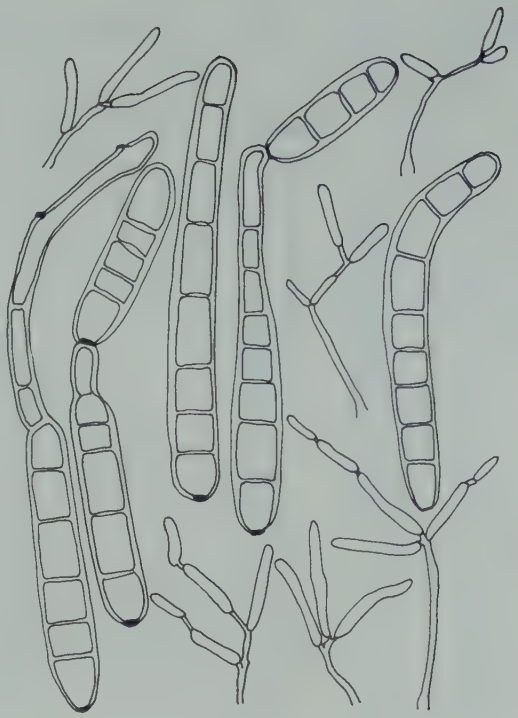


Fig. 23. Drechslera tuberosa

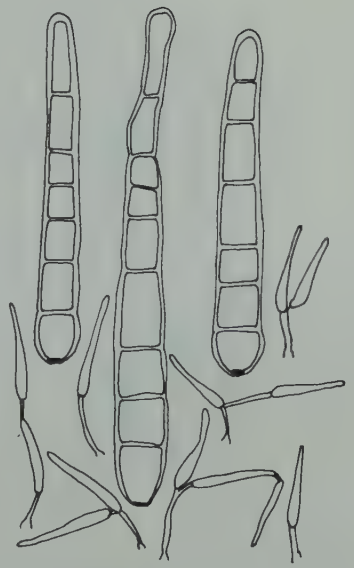


Fig. 24. Drechslera dictyoides f. sp. dictyoides

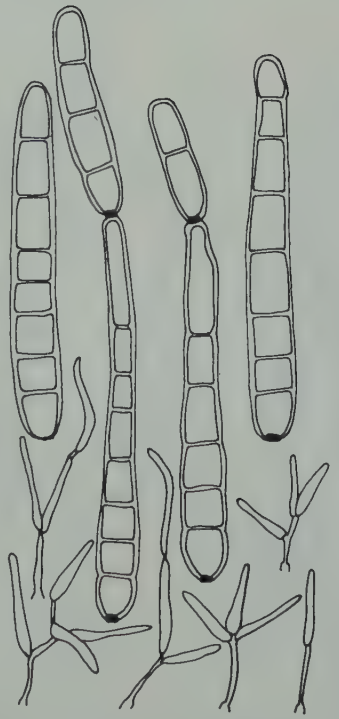


Fig. 25. Drechslera dictyoides f. sp. perennis

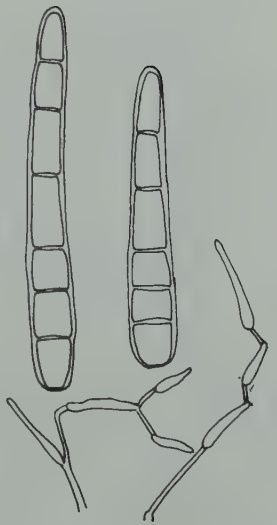


Fig. 26. Drechslera catenaria

as shown in Fig. 22. The latter pattern was observed when infected barley seeds were subjected to the freezing method of LIMONARD (1968). This species can also be distinguished from *D. teres* by having dark brown conidiophores bearing conidia of more or less the same colour, the latter appear slightly oblong instead of cylindrical under stereobinocular microscope.

Drechslera tuberosa also resembles *D. teres* in its general growth pattern and by having conidia in chains of 2 or 3. This species is, however, identified chiefly by its well formed conspicuous secondary conidiophores. Only few seeds of barley were found infected by it as against the common occurrence of *D. teres* in barley and may, therefore, not present much difficulty in routine identification. SHOEMAKER (1962) mentioned that *D. teres* seems to be restricted to barley on which it causes net blotch, whereas *D. tuberosa* causes leaf spot in many grasses including barley. Moreover he pointed out that the basal cell of the conidium in *D. tuberosa* is longer than wide and regularly bears secondary conidiophores whereas the basal cell of the conidium in *D. teres* is rather inflated with constriction at the basal septum and has no secondary conidiophores. He described the cells of the conidium as isodiametric appearing like a string of beads. In our observations secondary conidiophore like germ tube protrusions with conidia attached as observed by NISIKADO (1928) have also been found in *D. teres*. The conidia of *D. teres* from some seed samples of barley did not show inflated basal cells and the cells were not isodiametric. Other workers have also found that this is not a constant factor (PUTTERILL 1954, KENNETH 1962). However, all isolates of *D. teres* in our investigation produced mycelial tufts in full agreement with the previous descriptions.

Group 8. *Drechslera dictyoides* f. sp. *dictyoides, D. dictyoides* f. sp. *perennis* and *D. catenaria*.
(Figs. 24-26)

The species belonging to this group are characterised by obclavate conidia which show tendency to form chains. Conidia in chains were frequently observed in *Drechslera catenaria* where the secondary conidiophores are comparatively more pronounced. The two *formae speciales* of *D. dictyoides* showed no perceptible difference in their growth and it seems that they can only be identified on their host specificity. On the seeds there is no difference in the conidiophore

length. But in *D. catenaria* in most cases the conidia are borne singly at the apex, sometimes 2 or 3 conidia acropleurogenously. Commonly they occur in chains of 2 or 3. In *D. dictyoides* the conidia are borne acropleurogenously at the rate of 2 to 5 or more. The basal cell of the conidium in this species is broader than in the former and inflated with constriction at the first septum in most of the cases; this character is even visible under stereobinocular microscope when viewed carefully. In *D. catenaria,* on the other hand, the basal cell is rather long, hemiellipsoid as stated by SHOEMAKER (1962), and similar to that shown in the paper by ANDERSEN (1959), secondary conidiophores are also present. The inflated basal cell and constriction at the first septum of the conidia in *D. dictyoides* should be taken into consideration as a distinguishing character from *D. catenaria.* In *D. dictyoides,* chains of 2, rarely 3 conidia have been observed but they are not as common as in *D. catenaria.*

STANDARD BLOTTER METHOD VERSUS FREEZING METHOD

LIMONARD (1968) mentioned that in many samples higher percentages of *Drechslera* are found after freezing. This may partly be due to increased ease of observation which renders results more reliable. He studied *D. avenae* and *D. sorokiniana* in oats and *D. graminea, D. teres, D. siccans,* and *D. sorokiniana* in barley. All these species except *D. siccans* were also studied by us under the two testing conditions on blotter and the results are presented below:

TABLE III.

Infection percentages of *Drechslera* spp. in barley and oats studied by two different testing methods.

Host	Pathogen	Standard blotter method		Freezing method	
		Sample number			
		1	2	1	2
Oats	*Drechslera avenae*	68.0	82.5	81.0	77.0
Barley	*Drechslera graminea*	9.0	1.0	30.0	7.0
	Drechslera sorokiniana	34.0	53.5	34.0	63.0
	Drechslera teres	6.0	0	20.0	0

There was an increase in percentage of *D. graminea, D. sorokiniana* and *D. teres* in barley by the freezing method. Since these observations are based on few samples only more samples need to be tested by the two methods not only for *Drechslera* but also for other important fungi before drawing conclusions.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. M. B. ELLIS, Principal Mycologist, Commonwealth Mycological Institute, Kew, Surrey, for his valuable suggestions, help in examining the herbarium materials and confirmation of identifications during senior author's visit to CMI. Thanks are also expressed to DR. MARY NOBLE, Edingburgh, Scotland, DR. J. DE TEMPE, Government Seed Testing Station, Wageningen, Netherlands, Dr. JOHS. JØRGENSEN, Government Seed Testing Station, Lyngby, Denmark, Mr. STURE KARLBERG, Government Seed Testing Station, Solna, Sweden, for providing infected seed samples and to Mr. HENNING ANDERSEN, Government Plant Protection Service Hellerup, Denmark, for providing seed and for valuable suggestions.

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